

CONTROLLED IMPACT DEMONSTRATION [CID]

HEARING BEFORE THE SUBCOMMITTEE ON TRANSPORTATION, AVIATION, AND MATERIALS OF THE COMMITTEE ON SCIENCE AND TECHNOLOGY HOUSE OF REPRESENTATIVES NINETY-NINTH CONGRESS

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CONTROLLED IMPACT DEMONSTRATION [CID]

TUESDAY, APRIL 2, 1985

HOUSE OF REPRESENTATIVES, COMMITTEE ON SCIENCE AND
TECHNOLOGY, SUBCOMMITTEE ON TRANSPORTATION,
AVIATION AND MATERIALS,

Washington, DC.

The subcommittee met, pursuant to notice, at 1:10 p.m., in room 2318, Rayburn House Office Building, Hon. Dan Glickman (chairman of the subcommittee) presiding.

Representatives present: Glickman, Reid, Nelson, Lewis, Boehlert, Packard, and Carney.

Staff members present: Curt Stanford, technical consultant; and Harriet Smith, technical consultant.

Mr. GLICKMAN. To begin this morning, I would say to the audience and the witnesses, especially to Admiral Engen, we may be having votes periodically. We have this issue of the McIntyre-McCloskey Indiana House race, and if you are one of them, you would think the issue is as important as the issue we are talking about today. So we will be having votes on that, and we may have to leave and come back.

I also would like to welcome Mr. Carney from New York, who ran away from this committee last year to go on the Armed Services Committee. But he was a most productive member, and he served as the ranking member, and he was very intimately involved in this operation.

In fact, weren't you out there when it happened?

Mr. CARNEY. That's correct, Mr. Chairman.

Mr. GLICKMAN. So in any event, let's begin. Today we will hear the preliminary results of the controlled impact demonstration conducted at Edwards Air Force Base by the FAA and NASA last December 1.

This subcommittee devotes a large amount of its attention to the prevention of accidents, but the facts of life are that accidents will probably occur. In that case, we have a vital interest in providing the best that technology has to offer to assure the maximum potential for survivability for crash victims.

Once passengers have survived the impact of a crash which involves the structural integrity of the aircraft, the primary hazard is from fire and toxic products from burning fuel and cabin furnishings. Fire attenuation, blocking, and extinguishing, and escape routes and aids to escape in the limited time permitted, are all elements to be considered for survival from a crash.

The controlled impact demonstration was designed and conducted at a cost of about \$12 million to give us our first carefully re-

corded look at the many factors in play in a near-real-life crash. This is not your everyday opportunity.

In addition, the test was designed to observe and measure or perhaps even validate the results of many years of experimental development of fuel additives for post-crash fire inhibition, in this case, a misting and vapor suppressant, to reduce the explosive intensity or fireball common to spilled volatile fuels.

Admiral Engen will describe the design of the test, some of the occurrences during the test, and the preliminary results as he sees them. Then we will hear from Dr. Martin of NASA and Dr. James McAbee of ICI Americas, Inc. for their report on the several technical aspects of the test as derived to date.

Now, I know that there was some concern when those people who were out there saw this enormous fireball occurring and thought that the test was a failure. It's my understanding, based upon the initial determination and assessment of the data that in fact not only was the test not a failure but the test was probably the most significant experiment in air safety perhaps in modern history and will provide a great deal of very valuable clues as to how we can make air travel a lot safer.

Now I would like to call on Mr. Tom Lewis, the ranking member. Mr. LEWIS. Thank you, Mr. Chairman.

This is a hearing that is of great interest to all of us. Flying on U.S. schedule air carriers, as you well know, is one of the safest modes of transportation available to us. We both arrived back within Washington within 24 hours, Mr. Chairman.

However, perception is often more important than reality. And when a plane crashes, killing all of its occupants, the public is not calmed by statistics showing the relative safety of flying. This is particularly true for accidents involving fire. There is a special fear associated with being trapped in a burning aircraft. So anything we can do to enhance cabin fire safety, such as through improved materials, is certainly worthy of our attention. Development of a fuel additive that would retard postcrash fires is also a worthy goal.

I am aware that there was great disappointment with the results of the AMK experiment. However, there were many important worthwhile experiments in the CID program. I am confident that the results of this program will show that it was indeed a very successful program.

Thank you, Mr. Chairman.

Mr. GLICKMAN. Thank you.

Mr. Carney, would you care to make, since you were involved in this thing, any opening remarks?

STATEMENT OF HON. WILLIAM CARNEY, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF NEW YORK

Mr. CARNEY. Thank you, Mr. Chairman. As you have stated, I went out to California to observe the crash, and I was so impressed with the test that I requested that you hold this hearing. So I really do appreciate being invited here, even though I am no longer a member of the subcommittee. I obviously have to pay the punishment. I am down three seats farther than I should be.

Mr. GLICKMAN. Mr. Carney, are you aware we have moved you to the left, not the right? [Laughter.]

Mr. CARNEY. I don't think that would ever happen.

I know a lot of people involved with the tests were disappointed, Mr. Chairman. For those who have equated success of the tests with the successful demonstration of the antimisting kerosene, this was understandable. So much time and effort had gone into the flight test, all for one short flight, and everything had to go right. So, it was natural that there would be a letdown feeling after the crash. And I am sure this general feeling of gloom after the crash contributed to the negative press coverage following the test.

However, to those who thought the test was a failure, I can only say that experiments are conducted to learn something, not to prove something. I saw this test as a huge success. I saw a 200,000 pound airplane carrying many different experiments on crashworthiness and fire safety, fully instrumented, take off and crash on target as advertised. It was awesome watching that big bird take off over Rogers Drylake, knowing the guy behind the wheel was a dummy, and then watching it return and crash right where it was supposed to.

I am sure a lot of valuable data was obtained from the test. That more than justified, as far as I am concerned, the \$11.8 million that we spent. And this data will lead to even safer aircraft in the future. The test was definitely not a failure.

We stood at that particular time, looking at the antimisting kerosene, and we were on the verge of making a decision, Mr. Chairman, as to whether we should spend money to retrofit the whole airline industry for antimisting kerosene, and I believe the cost of that was projected to be \$3.5 billion. I think by testing this as thoroughly as we did, we avoided doing just that. And we still, in my opinion, should continue.

The word out there in California was this would be the last test. I hope that's not the word in this committee, I hope it's not the word within the FAA community now, because I think we should go forward to try to find a way to suppress the fires that are caused by fuel, because, indeed, we can save a lot of life.

We are privileged to have the safest airline system in the world, and that is no short task. The FAA has done a marvelous job, and this is one demonstration of the type of work that they should continue to do.

So I would hope, Mr. Chairman, that those who were negative as far as the results of this test were concerned will learn to appreciate precisely what the American taxpayer got out of this \$11.8 million investment, and I think that was an enormous amount of information for a small amount of money.

Mr. Chairman, I again thank you for inviting me here today, and I look forward to seeing some of the films which I had an opportunity to see while out in California. But I haven't seen all of them, and I understand it's going to be quite a show.

Thank you, Mr. Chairman.

Mr. GLICKMAN. Thank you. Yes; obviously, we have the video displays here.

Does either Mr. Nelson or Mr. Reid wish to make an opening statement?

Mr. NELSON. I just want to say, Mr. Chairman, that I am delighted to see Admiral Engen here. I have had the privilege of working with him on some of the intrusion problems in the restricted airspace at the Kennedy Space Center that we have had, and he has been just a delight to work with. I am looking forward to your report.

Mr. GLICKMAN. Thank you.

Mr. Reid.

Mr. REID. I have no statement, Mr. Chairman.

Mr. GLICKMAN. Thank you.

Don, please proceed.

STATEMENT OF ADM. DONALD D. ENGEN, ADMINISTRATOR, FEDERAL AVIATION ADMINISTRATION, ACCOMPANIED BY TONY BRODERICK, ACTING ASSOCIATE ADMINISTRATOR FOR AVIATION STANDARDS; NEAL BLAKE, DEPUTY ASSOCIATE ADMINISTRATOR FOR ENGINEERING AND LOGISTICS

Admiral ENGEN. Thank you, Mr. Chairman. Members of the subcommittee—and Mr. Carney, if you will let me keep you out there.

Mr. CARNEY. I had to move a little right, Admiral. [Laughter.]

Admiral ENGEN. If I may, Mr. Chairman, I would like to introduce my new Deputy Administrator, Mr. Dick Jones, who is here today, and Mr. Tim Cole, who has kindly assented to replace Mr. Garland Castlebury. These two fine gentlemen will be working with you and your committee in the future. I wanted to be sure that they had an opportunity to meet you, sir.

I have with me today Mr. Broderick, who is Associate Administrator for Aviation Standards, and Mr. Blake, on my right, Deputy Associate Administrator for Engineering and Logistics.

I am very pleased that we can appear before you today. Knowing your penchant for getting at the heart of matters, I have condensed my statement and I have just a few short remarks.

Mr. GLICKMAN. Your entire statement will appear in the record.

Admiral ENGEN. We are going to discuss today the impact demonstration, the controlled impact demonstration, or CID, conducted by the FAA and the National Aeronautics and Space Administration last December. I am accompanied, as I told you, by these two gentlemen on my left and right.

Following my comments, Dr. John Martin, NASA's Associate Administrator for Aeronautics and Space Technology, will discuss the NASA activities.

As the subcommittee is aware, in 1980 the FAA formalized an aircraft safety plan which was keyed to producing a number of regulatory actions in the 1982-85 time frame. The plan called for work in six major areas: crashworthiness, antimisting kerosene, cabin interiors, a large transport category aircraft controlled impact demonstration, emergency evacuation, and aircraft supporting systems.

This afternoon I will report on some of the preliminary results resulting from our controlled impact demonstration conducted on December 1, 1984. The CID, as it's called, program was a joint FAA-NASA research development undertaking that we did with the support from the National Transportation Safety Board, the Department of Defense, industry, and the British and French Gov-

ernments. Jointly financed by FAA and NASA, the CID represents an \$11.8 million investment in air safety. Of this amount, FAA expended \$8.1 million and NASA expended \$3.7 million.

FAA, as the overall program manager, was responsible for the antimisting kerosene effort, the cabin fire safety work, and some of the structural crashworthiness experiments.

NASA developed the data acquisition system and remotely piloted control system, or RPV, for the aircraft. And a NASA pilot, Fitz Fulton, using the RPV system, flew the aircraft into the impact site. And I wish to tell you that that was no small feat. It was very finely done.

In addition to managing the flight program, NASA had experimental seats aboard the aircraft, and currently is analyzing the effects of the impact forces on the structure.

The CID scenario was designed to be representative of an impact survivable accident. Now, by this we mean an aircraft accident in which the fuselage maintains habitable space and some passengers and crew would be able to survive the crash impact forces.

The aircraft used in this demonstration was a Boeing 720 four-engined intermediate jet airplane, a transport that entered the airline service about the mid-1960's. At 9:13 on December 1, the CID aircraft took off from Edwards Air Force Base in California for its remotely piloted flight. The B-720 was fueled with 11,325 gallons of inline blended antimisting kerosene. And I would like to show a video as soon as I complete my comments here, Mr. Chairman, of that flight and the crash that resulted.

The aircraft was climbed to 2,300 feet above ground level and flown along a predetermined flight path to intercept a simulated instrument landing system to begin its descent. The aircraft touched down in a slightly nosedown, left-wing-down attitude, slightly short of the target area. The aircraft passed through the wing cutters in a yawed condition which resulted in destruction of the right inboard engine. Some of the cutters then penetrated the left wing and fuselage.

This resulted in separation of the right wing, destruction of the keel beam, and other portions of the structure. Ignition of degraded AMK flowing from severed fuel lines and oil and hydraulic lines released when the cutter penetrated the engine resulted in a very large fuel-fed fire. The yawed condition of the aircraft, combined with the opening of the lower portion of fuselage, resulted in fuel penetration and subsequent fire in the lower fuselage. This fire penetrated the cabin through the floor.

However, I think it's interesting to note that the left wing was not penetrated and it did not burn and it did, in fact contain its fuel.

Although the impact scenario deviated from the plan, the test validated that the parameters selected for the crash scenario would result in survivable impact. It further indicated that the airframe designs in current use would remain essentially intact in this type of an impact.

Ninety-seven percent of the photographic and electronic data recorders worked successfully. Data on the structural response of the fuselage, the wings, the seats, restraint systems, galleys, and over-

head compartments were successfully telemetered back to the ground station, as well as recorded onboard the aircraft.

This data will be used to verify and refine the analytical models and provide impact force characteristics for testing of advance seats, restraint systems, and composite structures. The seats, except for one set at the fuselage rupture, remained in place, and the restraint systems restrained the occupants.

Tests of hazardous material containers, new flight data recorders, and cockpit voice recorders were successful. The test demonstrated the operational compatibility of AMK with the aircraft and engine fuel systems and the technical feasibility of degrading anti-misting kerosene.

In the area of AMK fire protection, the location of the fire source at the leading edge of the wing precluded a demonstration of the major advantage of AMK fuels; namely, that the formation of large fuel droplets prevents the forward propagation of a fire and attachment of the fire to the aircraft. The use of the additive, however, appeared to reduce the heat transmitted to the fuselage by the fireball. There was evidence that the seat cushion fire-blocking layers delayed the spread of internal flame.

Now, we have concluded that the CID flight ended in a survivable impact and the fuselage, which remained essentially intact, provided the occupants with a habitable post-impact cabin space. Was the CID worth the investment? We think it was. It provided extensive impact data and information on the response of an aircraft structure to real impact forces.

It also highlighted the fact that accident scenarios are indeed unpredictable. Based on the preliminary results available from the CID, I am proceeding with all of our anticipated rulemaking actions except that with respect to AMK. We will wait for the complete analysis of CID data before deciding on further action with regard to the AMK.

Now, the video that you are about to see will cover most of the points I have already addressed. I believe that it will provide you with a realistic illustration of what actually occurred on December 1 at Edwards Air Force Base.

When the video is complete, Mr. Broderick, Mr. Blake, and I would be very pleased to answer any of your questions, sir.

Mr. GLICKMAN. All right. Why don't we begin the video? And I think we are going to need to turn the lights off.

Mr. CARNEY. Mr. Chairman.

Mr. GLICKMAN. Yes.

Mr. CARNEY. Before you start, I have a 2 o'clock appointment, and I would just like to get something on the record. I did say that the guy behind the wheel was a dummy, and I see Fitz Fulton out there. I want to make something clear. [Laughter.]

The guy behind the wheel of the plane was a dummy, but Fitz Fulton, who flew that plane from the basement of the building we were all in, did a marvelous job of bringing that bird right back to where it was supposed to be landed. Thank you.

Mr. GLICKMAN. OK, why don't we begin.

Will you be narrating this as it's going?

Admiral ENGEN. No, sir, this is with sound.

Mr. GLICKMAN. OK.

[Film shown. Narration follows:]

On December 1, 1984, a remote-controlled four-engine transport jet took off from Edwards Air Force Base, CA, and crashed into a barren patch of nearby desert.

This controlled impact demonstration was a joint research and development program by the Federal Aviation Administration and the National Aeronautics and Space Administration. The analysis of CID data continues, and will for some time.

But the learning process has already begun. The FAA designed the controlled impact demonstration to underscore results of exhaustive research in two areas of aircraft safety: improved crash protection and reduced post-crash fire hazards. Despite the fact that the crash did not go exactly as designed, CID did achieve its primary objectives:

The test did generate a great amount of impact data, including electronic data and over 28,000 feet of film, information that will validate tests used to predict structural damage;

New transport seats and restraint systems remained in place and restrained the occupants;

New flight data and cockpit voice recorders, including the Navy's flight incidence recorder-emergency locator transmitter unit, survived and worked successfully;

Hazardous material containers remained intact through the impact;

There is evidence that fire-blocking seat layers protected the seats and delayed the spread of flames;

Aircraft propulsion and fuel systems operated normally on AMK, antimisting kerosene;

The prototype engine fuel degraders did break down AMK's antimisting characteristic prior to combustion;

Although there was considerable fire and smoke, the AMK fuel did reduce heat transmitted to the fuselage, preventing a burn-through;

And the remote piloting system did guide the aircraft down close to the projected impact area;

Finally, the fact that the left wing struck the ground first and neither ruptured nor spilled fuel underscored the validity of the current FAA fuel containment requirements. Though fuel containment was not a primary objective of CID, this information has proved useful.

The CID's crashworthiness tests were as important to the FAA as the fire safety tests. The crash protection objectives were, first, to obtain data on impact forces and their transmission through the structure to the seats and occupants; second, to evaluate the performance of existing and advanced energy-absorbing seats; and third, to compare tests used to predict structural behavior with an actual crash.

But before any of this could be done, the FAA needed a scientifically controlled impact. At the heart of the experiment was the need to find and simulate a common, survivable aircraft accident. To do this, the FAA first had to identify the problems that might cause injuries or fatalities even in a survivable crash. A thorough examination of past accident investigations determined some specific failures: seat mechanisms, restraint systems, seat-to-floor at-

tachments, fuselage and cabin floor structures, overhead racks, galleys, and other components which could cause injuries or fatalities.

This work led to the model controlled impact demonstration. The test called for the CID to descend at a rate of 17 feet per second; to have a longitudinal speed of 150 knots, and to have a pitch angle of 1° nose up, with minimum roll and yaw. It wasn't enough to simply base predictions from the scenario on paper. Prior to the actual CID experiment, there had to be tests.

At its technical center near Atlantic City, the FAA evaluated its model accident, first with a series of fuselage section drop tests. Instrumented dummies provided data on transmission of impact forces to seat occupants. A similar test adding luggage to the cargo hold measured the cushion this buffer gives upon impact. Sled tests verified longitudinal impact forces. Certainly, the largest and perhaps most telling test was the dropping of a scrapped Boeing 707 under the planned impact conditions. Its fuselage survived the shock and remained intact, although the lower fuselage was crushed somewhat and the cabin floor was deformed.

The stage was then set for the CID crashworthiness tests. The fire resistance tests were another story.

Over the last 6 years the FAA has examined AMK's potential for protecting commercial transports from ignition of misted fuels. Progressing from laboratory and small-scale tests to full-scale crash tests, all research indicated that AMK would be effective in preventing this problem. The controlled impact demonstration was an opportunity to use AMK in a realistic impact-survivable crash.

To make absolutely sure AMK would be released, eight wing-opening devices were placed in the impact zone. To ignite the fuel, a prime test requirement, the aircraft tail cone was equipped with two kerosene burners designed to fire when impact forces reached 1.5 G's. They would continue firing approximately 9 seconds, the expected slideout time of the aircraft.

In addition, 12 high-intensity approach light towers were installed in the impact zone and the slideout region, and the ground was covered with railroad trap rock to add extra ignition potential.

The CID aircraft's four engines were not considered likely AMK ignition sources. Their positions, suspended well forward on the wings, made the chance of ejected fuel reaching them and then actually entering the inlets quite remote. This probability occurs only in the rarest of accidents.

From the moment the CID aircraft smashed down onto the desert floor, the model accident was gone. The plane struck the ground somewhat short of the target, with the left outboard engine low, and yawed to the left. It remained yawed to the left as it slid into the wing-opening cutters.

The first cutter entered the right inboard engine at about the seventh stage of the compressor. It slashed through the engine, broke free, then tore through the underside of the wing, inboard of the engine, releasing a massive volume of fuel.

At approximately one-tenth of a second after impact, the first ignition occurred, on the inboard side of this engine. The highly unlikely had happened. Postcrash examination of this engine showed compressor rotation stopped instantaneously. Why ignition occurred requires a description of the damage caused by this impact.

This is an engine identical to the one that ignited, with the cowl- ing removed. Entering fuel is routed to the degrader where the AMK fuel's antimisting characteristic is removed, restoring all its normal kerosene properties. It then passes down the right side of the engine to the main fuel pump.

When the cutter struck, it destroyed the degrader inlet and outlet lines, and cut through the lines carrying the degraded fuel to the engine fuel pump. It also destroyed the engine gear case, releasing its contents in a misted form. In addition, the hydraulic pump, which is also mounted in this gear case, was struck and released a misted high-pressure hydraulic fluid. The spark that set all this off most likely came from the cutter tearing through the engine. The burning fluids heated the metal case of the engine which created an extremely hot and continuous ignition source.

Meanwhile, other cutters entered the wing and fuselage. Post-crash examination revealed severe damage to the keel beam in the wing box area, massive holes in the lower fuselage through which burning fuel could enter. This rip in the underside of the aft fuselage is an example of the effectiveness of the cutters' work. Similar and even larger openings were made under the wing in several places.

Anyone who witnessed the CID test, or saw the televised shots of it, will probably have the same question: why did the AMK-fueled plane have such a large fire?

AMK is designed to resist burning under crash conditions. It turns to a coarse, nearly incombustible spray. But AMK can be made to fail and to burn up violently. It can be sheared too hard, as was done in this sequence by increasing the impact velocity above the protection velocity, which is determined by the amount of additive in the fuel.

The only other way for AMK to fail and then burn is to give it an intense, continuous ignition source. In the CID test, the destroyed engine provided just such a source. It stayed with the fuselage throughout most of the slide and was located right at the fuel release point.

So, how bad was the fire? Viewing the CID from impact to final rest shows the external fireball about the fuselage lasted roughly 9 seconds. Looking at the fuselage after the initial fireball lifted showed little evidence of heat damage. Paint was intact and only slightly sooted, indicating heat transfer was minimal.

Later, the FAA investigated this phenomenon. In these scaled tests, jet "A" kerosene released into a 120-knot airstream, allowed to mist, and then ignited, raises the temperature of an aluminum panel 7 feet downstream to 650 degrees Fahrenheit or more. Metal failure occurs above 475 degrees.

In the same test using AMK, a noticeable cooling takes place. More of the AMK reaches the metal surface in liquid form, which keeps it cooler. Until all the liquid has evaporated, the temperature of the fluid cannot rise above the boiling point of AMK. In this case, the aluminum panel reached only 200 degrees Fahrenheit.

During the controlled impact demonstration, large amounts of liquid AMK evidently flowed over the fuselage, keeping the temperature relatively cool. Because of the lower heat, the AMK fire-

ball did not burn through the fuselage and ignite the interior materials, even though insulation had been removed to install test instrument lines.

The fire inside the CID aircraft started with burning fuel that entered the cargo compartments through the holes ripped in the bottom of the fuselage by the wing openers and, possibly, through a forward cargo door that opened on impact.

This fire caused a quick buildup of smoke in the cabins. The forward-cabin visibility was obscured rapidly after the aircraft came to rest. The aft cabin took nearly 20 seconds. Intermittent flames entering the cabin door during the slide appear to be burning fuel vapor, but weren't enough to ignite interior materials. Had there been a sidewall cargo liner in the CID aircraft, as most commercial aircraft carry, there would have been fewer flames and a much longer time for smoke to fill the cabins. These liners were removed to facilitate installation of cables and were not replaced.

But could anyone have survived the CID crash? The FAA's answer is, "Most likely, yes." The fuselage remained essentially intact and was a livable area even though the main structural feature, the keel beam, was severely damaged by one of the wing openers. Nonetheless, all seats remained in place except for one row of triple seats near the floor break in midcabin, which was dislodged.

Dummies were used to measure "impact loads" or "forces." Anthropomorphic dummies, in white shirts, respond like people and were instrumented to record impact forces. The other dummies were medivac types used to simulate occupant weight only.

Impact load pulses recorded throughout the fuselage remained within human tolerance levels. Seats and restraint systems performed as designed. Please note the anthropomorphic dummy in the center seat in this shot, the dummy in the braced position. You will notice that it moves very little during impact and slideout.

In this shot you can tell the pilot experienced severe, but survivable, impact loads, but was effectively restrained by the shoulder harness.

Although we can never be absolutely sure, preliminary findings based on analysis of high-speed motion picture film indicate some people could have escaped from the aircraft. And existing accident reports indicate passengers in the aft cabin probably could have escaped even after smoke had entirely filled their area. Accident investigators found all six exits operable, but not all equally usable.

After the 9-second fireball, passengers could have exited through the left forward and right rear doors. The remaining four exits were either blocked by fire or of questionable use due to extensive smoke from the external fire.

This illustration shows the reconstructed fire and smoke condition for roughly 30 seconds after the aircraft came to rest.

For a controlled crash that didn't go exactly as planned, the CID test still accomplished its primary objectives. It yielded extensive impact data and information on the response of an aircraft structure in an actual crash. Since much of the data for rulemaking comes from small-scale and component testing, CID validated the results of previous tests in a full-scale accident environment. And

while it confirmed previous research, it also highlighted the fact that accident scenarios are unpredictable.

As the analysis continues, the controlled impact demonstration's effect on future aircraft safety will become clearer. Its crashworthiness and its survivability already mark a milestone of aviation safety research.

Mr. GLICKMAN. Fascinating film.

First of all, what I would like to do is ask you about the possible rulemaking which may take effect as a result of this test or not as a result of this test. And I wanted to go over that rulemaking. What specifically are you going to propose now in the areas of antimisting fuel and the area of seat standards and the area of flammable materials and anything else that you might have as a result of this test?

Admiral ENGEN. Mr. Chairman, as you know, we have a wealth of data to reduce with respect to the antimisting fuel, and we are doing that right now. What we are doing is we are compiling that data and evaluating it, and it's too early for me to say anything other than that I do not propose to go forward with rulemaking with respect to AMK at this point. It will be about July, early summer, before we have that data put together and we can make some evaluative judgment about the AMK.

With respect to the seats, I would like to let Mr. Broderick talk a little bit about the seats. As you know, the airplane was subjected to, I believe, about a maximum of 17 G's externally, which transmitted to about 7 G's because of the carry-through of structure and everything else to the seats. And we have been working on seat strength, as you know, for some time.

Mr. Broderick, would you make some comments, please?

Mr. BRODERICK. Yes, thank you. As you know, Mr. Chairman, we have testified before before this committee on seat strength standards. In September we published a summary of data available that we will use as a reference document in human tolerance for surviving aircraft accidents. That document also included a summary of our crashworthiness program, which leads this June to three major documents that will be published. We will have a general aviation dynamic test guideline document, a dynamic seat standard rule, together with an analytical modeling technique guideline document, or advisory circular.

Those documents, together with the reference to human tolerance in aircraft accidents, will permit us to require significantly increased survivability in the designs of seats for aircraft.

Mr. GLICKMAN. So you will be proposing a new seat strength standard rule this summer sometime?

Mr. BRODERICK. Yes, sir. In June is our proposed date this summer.

Mr. GLICKMAN. OK. You know, it was in 1982, I think, before you came onboard, Don, that the NTSB chairman, Mr. Burnett, testified before this committee and he criticized the FAA for disregarding that recommendation by the NTSB to improve seat strength standards. And in August 1982, or shortly after that testimony, this subcommittee as well as others, Mr. Mineta's subcommittee as well, recommended that the FAA, while continuing your plans on

this CID test, immediately upgrade seat standards based on state-of-the-art of technology.

Today Mr. Broderick has indicated that the FAA will issue a notice of proposed rulemaking for transport seat strength. I am just wondering, is that proposal based upon the seat strengths validated in the CID crash, or why have you decided now after all this time to go ahead with seat strength guidelines?

Admiral ENGEN. We have decided, Mr. Chairman, to go ahead at the time with improving the seat strength and improving the survivability in the seats. We have been working on it since that time, and even before then. You know, if you strengthen the seats, you then have to strengthen the floor to which they are attached, and in aviation, as you well know, it's one compromise after another. So you have to get things in balance. You could have the strongest cast-iron seat in the world and put it in an airplane, and it would probably come loose from the subfloor structure because it would be so heavy.

So you have to go at this and you have to do it in a way that it can be engineered into the airplane. We have been doing that. And the rule that Mr. Broderick is talking about that we will be talking about, the notice for proposed rule, in June really is a result of those 3 years of research and development. I know it appears slow, but we have wanted to walk through this and be sure it was right.

It is not as a direct result of the CID. However, we did validate the seat strengths for the seats that were in the CID airplane.

Mr. GLICKMAN. Now, will these seat strength rules be applicable to existing airplanes? Will there be a modification requirement to existing airplanes?

Admiral ENGEN. There will be no retrofit on the seat strength because of what I talked about, the subfloor structure, because when you strengthen the seats, you then have to go in and you have to change your floor structure. It would be for all aircraft built after a certain date.

Mr. GLICKMAN. Let me ask you this. Is it true that the seats in most commercial airplanes today are less rigid than the seats in automobiles?

Admiral ENGEN. That comes back to my previous answer, and I don't want to repeat myself. But it comes back to that previous point. I think I would hate to draw a comparison, but I imagine you could find some automobile seats that would withstand more than some aircraft seats. But that's the reason for the NPRM coming out in June, sir.

Mr. GLICKMAN. Now, with respect to the antimisting fuel, you indicated in the crash tests that you did not find that the fuel in any way gummed up the operation of the airplane in terms of the performance of the airplane. Is that correct?

Admiral ENGEN. I am going to let Mr. Blake respond to that. But I would like to say that I think it was a singular technical success, if you will excuse my qualification there, to have flown a four-engine jet transport airplane with fuel that's designed not to burn and you put it in and then you bring it out and change the qualities.

Neal.

Mr. BLAKE. Thank you. As you know, several years ago we identified a number of problems that had to be resolved in order to utilize the antimisting kerosene in the aircraft engine. We were able to run a series of tests both on a Convair 880 with a single engine and on the Boeing 720, and we were able to control the quality of the fuel and the various processes of degrading that fuel and to operate without any technical problems.

Mr. GLICKMAN. OK. So if an air carrier came to me and they said, "Mr. Glickman, we don't want to use this antimisting fuel because it will significantly reduce the performance of our airplanes," how would you respond to that?

Admiral ENGEN. Our evaluation of AMK to this date is that you get as much out of it as you put into it, and when it's degraded, it burns as effective jet fuel.

Mr. GLICKMAN. So again going back to the fire that resulted, which I think it turned some people off in terms of requiring this kind of fuel in aircraft, you're saying that the test data seems to indicate that that fuel itself and the fire that resulted from the crash in no way prejudices the use of that fuel at some point in time as part of a rulemaking procedure?

Admiral ENGEN. Yes. I would like to be very clear, though. I would like to say that we were disappointed in that the ignition point for the fire was so far forward, no one can control a crash or an accident and we have to accept what happened. There can be no alibi because you never can tell what's going to happen. So it was a very useful test in that respect. And I was personally disappointed that the ignition point was so far forward and that it did burn.

I don't see, based upon what I have seen to date—but once again I want to qualify this by saying we've got to reduce the data first—but I don't see at this point in time any reason to go forward with an NPRM on AMK. It didn't do what we wanted it to do even though it functioned perfectly. There was one scenario in which it burned, and I think we have to ask ourselves how effective is that fuel. And once again that's what we will be doing as we reduce the data.

Mr. GLICKMAN. Have you done any tests since the CID to determine why this fuel-fed fire took place and try to ascertain if there is any way to prevent that from happening?

Admiral ENGEN. We have not ever stopped our testing at our Technical Center in Atlantic City, Mr. Chairman. I am going to ask Mr. Blake to talk about the theory of what evolved and how we've analyzed what did occur.

Neal.

Mr. BLAKE. Yes. Thank you. In the video we tried to show the failure mode that was demonstrated by the CID, that if you do have an extremely intense ignition source, the fuel from the source on-back in the airstream will ignite. Of course, when the ignition source is removed, then the fire will terminate.

We have run the tests which you also saw in the video at JPL, which demonstrated the radiant heat when the fuel did ignite was lower for AMK than for standard Jet A. We have also duplicated the CID condition at the Technical Center subsequent to the CID event, and where you have an intense ignition source at the fuel release point it is possible to ignite, just as we saw at CID, the fuel.

Had the ignition been on the aft end of the aircraft, such as in an aft-mounted engine, the probability is the fire would have been entirely behind the aircraft.

Admiral ENGEN. But once again, it was an accident, and you can't plan that.

Mr. GLICKMAN. Well, I think you made the point that there is no way that you can schedule these things as you would like to have them scheduled, and that is probably why you're wise, at least with respect to the AMK, in avoiding a rulemaking procedure in this area. But I don't want to see you forever delay the possibility of improvements to fuel to reduce their combustibility, because if we have the capability of doing it, I don't want to wait another 10 years and 10 more accidents before reduced fuel combustibility takes place in the American airline industry.

Admiral ENGEN. I agree with you, sir, and we are and will continue.

Mr. GLICKMAN. OK. Now let me just ask you one other thing. Besides the seats and the AMK, is there anything else that the FAA is going to be doing rulemaking-wise. The fire-resistant materials, was that another area that you might want to mention?

Admiral ENGEN. Yes, sir. We have had a number of regulatory actions that we have put into place. Mr. Broderick talked about the advisory circular on human tolerance, which will be coming out in June. As you know, we have passed our final rule on fire extinguishers and smoke detectors, which will go into effect in June of this year. We have a notice for proposed rulemaking coming up with regard to general aviation crash-resistant fuel systems, which will come out this summer. We are going, of course, to put our notice of proposed rulemaking out on general aviation shoulder harnesses, upper torso restraint, in this summer, as well as the transport seat. We are going to do the transport seat strength that Tony spoke of.

We are doing analytical modeling on other crash dynamics, and we will be out with an advisory circular in June of this year. There are a lot of things that are going on, each one of which has been enhanced to some degree by the CID. But I would hasten to add that we have not been able to take any regulatory action specifically with regard to the CID yet. That will follow.

Mr. GLICKMAN. OK. Now, the fire-resistant, fire-blocking materials, you have proposed some regulatory proposals in the mill already on those, is there not?

Admiral ENGEN. Yes, sir.

Mr. GLICKMAN. All right. One quick thing, just a general question, final question. From the results of this test and everything else we know, just as a general question, what can we be doing now that we're not doing? Is there any general idea as to what we could be doing to make air travel more safe?

Admiral ENGEN. Well, I spend my 24 hours a day working and sleeping and dreaming about safety in air transportation in the United States. I am totally dedicated to it. I feel that we are doing so many things at the technical center with respect to materials and halon extinguishers, fire suppressants, fire retardants, doing the antimisting kerosene. Of course, there are operational procedures as well, and we're changing the air traffic control system vir-

tually. And I don't want to get into that now because that transcends this.

But those changes are coming about. It's a very dynamic safety atmosphere. I bring with me from the Safety Board a dedication to safety, aviation safety. And I am setting about trying to accomplish those things that have been in motion in the FAA, and I am continuing in the future to develop new initiatives. We are not going to rest.

Mr. GLICKMAN. Well, I am glad to hear that, and I have no personal problem with your role in that at all. I just saw some films here which indicated to me that airplanes may be able to be operated more safely than they are currently operated, and I hope that you are not going to be shy in pursuing those things.

Admiral ENGEN. No, Mr. Chairman, I promise you that.

Mr. GLICKMAN. OK. Thank you.

Mr. LEWIS. Thank you, Mr. Chairman.

Admiral, the tests that were shown in the video, what tests has FAA undertaken since December to more fully understand the CID-initiated fuel-fed fire?

Admiral ENGEN. Mr. Lewis, specifically, the tests that have been undertaken would be small tests done at our Tech Center, which are to corroborate something. But primarily, what we have done is we have taken the reams of data that we have—and I don't think we have it all reduced yet—we had telemetry, 10 cameras going, and we're reducing that data right now to make sure of what we have. It just takes a long time working 40 hours a week per individual to reduce that data.

To answer you specifically about additional tests that we've done, we have done no major tests since that time.

Mr. LEWIS. I see. I am curious as to how you came to the conclusion after looking at the aft section of the fuselage or the interior, where we had the flash fires from the vapors, that the statement could be made that there was a good probability that people could survive that crash. On what basis was that judgment made?

Admiral ENGEN. I think from the photographic evidence—and I am going to ask Mr. Blake to make a comment here—but from the photographic evidence that it was a passing flame, fuel misting that just kind of wisped through the cabin. And that's primarily on what we made that evaluative judgment.

Neal, would you care to make some comments?

Mr. BLAKE. Yes. Thank you. Normally, the cargo compartment liner which would be in an aircraft would eliminate the possibility of those flash vapors that you saw burning in the cabin. We had removed that liner to facilitate installing all of the instrumentation. But the evacuation assessment was made based on the fact that all of the doors were mechanically operable, and that the front left door was clear of flame for a fairly lengthy period of time, and that the aft rear door was relatively free of flame.

Now, the buildup in the smoke of the cabin was fairly rapid, particularly at the front, due to the fact that we had no cargo liner installed. At the back of the cabin there was visibility for about 15 to 20 seconds. Our experience has shown that a number of people could have gotten out during the visibility period and probably for

some period of time thereafter, just based on what has happened in past accidents.

As the film indicated, we can never be absolutely certain as to how many could have gotten out, but I think the general consensus of the accident investigators and others is that some could have.

Mr. LEWIS. Did you have any sensors in there to know what the temperatures were in the interior of the cabin during the fire, during the time of the flash fire?

Mr. BLAKE. We did not have any temperature or gas measuring equipment on board the aircraft, as the fire safety experiments were not the primary experiments. But just based on past accidents and what happens, we did have the film coverage of the interior that showed about when smoke obscuration took place in each area of the cabin.

Admiral ENGEN. Mr. Lewis, I might add that we went back over about 24 years and looked at all the accidents that were survivable in air transport airplanes—and I am going to pull a number out of the air—there were approximately 294 accidents, of which 99 of those were, we felt, survivable. And we put the criteria together for those accidents to help develop our analysis of the CID airplane. So it was based upon past hard data as well as what we observed.

Mr. LEWIS. Were there any real surprises with the test, or do you anticipate any further research in some of the areas as a result of the tests other than AMK?

Admiral ENGEN. Well, I think the surprise to me was that we had a fire generator which was when the cutter went into the seventh stage of the No. 3 engine far forward on the leading edge of the wing, and that presented the constant ignition source. And so that kind of came as a surprise. I think that other than that, the CID mission went very well. There is a wealth of material there in crashworthiness and survivability, and the fire was the surprise to me.

Mr. LEWIS. Do you think that the tests conducted up until now are adequate to say with certainty that AMK will cause no problems with fuel systems?

Admiral ENGEN. Did you say that AMK will cause no problems with what, sir?

Mr. LEWIS. That AMK would cause any problems with engine systems?

Admiral ENGEN. I feel quite——

Mr. LEWIS. Fuel systems.

Admiral ENGEN. Yes, sir. I feel quite confident that it has been demonstrated that AMK can be induced into the airplane's fuel system and degraded to burn satisfactorily at will, at command. It works.

Mr. LEWIS. Do you have any further tests anticipated where you may have another simulated crash to look at fire retardation materials for the interior of the cabins?

Admiral ENGEN. I know what Mr. Carney said, and at this point I would prefer to say that I want to reduce that data and see what we've got with respect to AMK and see where we are before I would make any judgment as to whether we should do it again or not.

Mr. LEWIS. Thank you.

Thank you, Mr. Chairman.

Mr. GLICKMAN. Thank you.

Before I yield to Mr. Carney, is this the first time an airplane of that magnitude has ever been remotely piloted?

Admiral ENGEN. Yes. Yes, sir. NASA did a magnificent job in this respect. They really did. This is the largest aircraft at the greatest gross weight of any remotely piloted vehicle.

Mr. GLICKMAN. Thank you.

Mr. CARNEY. Thank you, Mr. Chairman.

I might have seen a different accident than some of those folks out here who are saying that that was a survivable accident. I mean I am a layman, but there is no way I would ever be convinced that that was a survivable accident. I don't care how much data you crunch, Admiral, that was not a survivable accident. No way, no how. The test was a complete success from my standpoint because it did what it would do. It would prove to me that the AMK didn't work.

Admiral ENGEN. I know you want to continue, but let me just say that I said it was a postcrash survivable accident up to the point where it burned. And even so, Mr. Carney, in those 20 seconds that are available before the cabin was begun to be consumed by smoke and fire, egress is possible.

Mr. CARNEY. Admiral, we saw when the plane went through the cutters, the fire started immediately. An hour and a half later, over the loudspeakers, the guy was yelling, "We're out of water." Six crash trucks were out of water. The fire was still going. The fire never stopped. How does anyone get out of the plane in that fire? That fireball went on forever.

Admiral ENGEN. Your only chance for escape would be in the first 20 seconds, sir.

Mr. CARNEY. Well, good luck. I mean that fireball followed that plane. You are very optimistic, Admiral. You did a great test. But I could never believe that that was a survivable crash. Never. The flames stayed within the fuselage of the plane as it dragged across the desert, the rockbed that was set out in the desert. I just couldn't believe that that could be a survivable crash. I would not have wanted to be on that plane. [Laughter.]

Mr. CARNEY. Let me tell you that.

Mr. GLICKMAN. We are glad you weren't, Mr. Carney. But let me ask you a question. If the fuel had not been antimisting fuel, would the flame have been any different than if it were the antimisting fuel on it?

Admiral ENGEN. Yes, it would. And unfortunately, I don't have another clip that shows the difference between the two, but they're roughly comparable in the previous clip to the small-scale tests, and it would have been a vastly different flame pattern.

Mr. CARNEY. That's similar to saying that a 300-kiloton bomb is different than a 400-kiloton bomb.

Admiral ENGEN. We're talking technology, yes, sir. I agree. I wouldn't argue with you. And I wouldn't want to be on the airplane either.

Mr. CARNEY. This is the important thing. The fuel I think worked from the standpoint that it could be degenerated and the additive worked and the engines, everything went very, very fine,

and we have to continue to test and to find ways to make it a little bit more proficient, you might want to say, from retarding flame. But that fireball, you could see over the—I mean the fireball, I am not a good judge of height, but that had to be over 100 feet high or 50 to 100 feet high.

Admiral ENGEL. In the total context, Mr. Carney, I don't disagree with you and I wouldn't argue with you. But in the context of crashworthiness and survivability, if you look at the crash impacts, that was a survivable accident.

Mr. CARNEY. Absolutely.

Admiral ENGEL. That's what we're saying.

Mr. CARNEY. I would agree with you on that, Admiral, from viewing the films and that type of thing, inside the cabin, that type of thing. It wasn't survivable from the standpoint of the fire. If the AMK had worked, I think it would have been quite survivable.

We have tested the AMK up in Atlantic City, NJ, on a test bench. And we went along and it seemed to work, and it called for the FAA to spend this money to make the final test, an accident. You can't program an accident, as you said. I thought it was absolutely marvelous that that plane turned around. As much as I thought it was marvelous, I was thinking of how marvelous the people in Burbank must have thought, because that's where it was heading, you know, that it did turn around and come back and land. [Laughter.]

Mr. CARNEY. But you know, that aspect of it was a success. But I didn't see the antimisting kerosene being much of a success from the standpoint of not causing the fireball to stay with the aircraft and not causing an enormous amount of flame.

I mean you could see it on the faces of everyone. And if you wanted a barometer for the success of the test, what you had to do at the moment of the crash and for 30 and 60 and 120 seconds later, look at the faces of the gentlemen from ICI.

Mr. GLICKMAN. Will the gentleman yield?

What I want to know is what about the faces on the dummies inside the airplane more than the people with NASA or the FAA on the outside. And I don't want to get engaged in an argument on this thing, but what you are telling me is the skin temperature was dramatically lower and the fact of the matter is that had there been the insulation around that airplane, the smoke would have been dramatically less.

So while people were shocked because the fireball burned, I want to make sure I am getting from you what your testimony is. Did the antimisting fuel reduce the danger to those dummies and the people they represented from what it would have been if there had been regular fuel in that airplane?

Admiral ENGEL. In my considered opinion, Mr. Chairman, the antimisting kerosene did reduce the damage to the airplane. The damage came from continued pooling and burning after the ignition source was lit off. But it did indeed—the initial impact, as seen from the sides of the airplane and the pictures that we showed you of the decal and the sides of the fuselage show that it went through the fire and it was virtually not even scorched.

Mr. GLICKMAN. I guess—go ahead. I am sorry.

Admiral ENGEN. You know, it depends where you're sitting. And I know exactly what you're saying. But it depends where you're sitting.

Mr. GLICKMAN. Literally. Literally.

Admiral ENGEN. Literally.

Mr. CARNEY. Admiral, you and I were delayed from going out to the crash site because it burned for an hour and a half. One place I would not have wanted to be sitting in was that aircraft. You couldn't convince me with all the data that the fuel worked. It burned for an hour and a half. It stayed within the fuselage of the plane.

In fact, from looking at the plane you could see a hole up forward of the wings where it just literally, in my estimation, burned right through right behind the cockpit on the right-hand side of the plane. The heat, I believe, caused that to happen. And it's on the film right there. We looked at that plane when we were standing there. It was amazing. This was an hour and a half later.

I don't know how many airports respond with six firetrucks that happened to be right there when the accident happened, and they ran out of water and the flames were still going an hour and a half later.

Admiral ENGEN. Hopefully, every major airport will respond just that way, Mr. Carney.

Mr. CARNEY. I would hope so. But I mean we know they can't.

Admiral ENGEN. Yes.

Mr. CARNEY. I mean you can't position crash trucks at a precise point in an airport like you could there. You knew where the accident was going to be.

Admiral ENGEN. We are prepared to respond in that way, sir. Let me just say, please, that it was a test. It was a test. And yes, you saw the fire there, and yes, it did burn because of all the reasons that we have explained to you here, which says why the AMK didn't function as we had thought it would.

But as far as being crash survivable, it was a survivable crash in that context. As far as having a fuselage enclosed envelope with respect to G forces, it was survivable. Some people could have gotten out of it. You can't say that you couldn't get out of it, Mr. Carney. I wouldn't want to sit in it. But I have watched an awful lot of airplanes crash, and I don't relish it very much. The initial impact as it came to a stop was a survivable crash.

Mr. CARNEY. I respectfully disagree with the admiral.

Mr. GLICKMAN. On that note, I will yield to Mr. Packard.

Mr. PACKARD. I am sorry I had other activities that kept me from even seeing the film. But let me ask just one simple question. In your test did you find one portion of the aircraft more safe than other portions of the aircraft?

Admiral ENGEN. There are a couple of areas, and I am going to let both Mr. Broderick and Mr. Blake make a comment here because I would like to cover this fully because that is a very important one.

I think if you look at the cabin itself, I think that you would see that the forward cabin was OK and the aft cabin was OK. At the juncture of where the fuselage buckled—and in the film clip here we saw a set of three seats that came loose; that was the point at

which most of the force was exerted, and that would have been the least safe place.

But let me ask Mr. Broderick to comment on seat blocking, and I will ask Mr. Blake to comment on the remainder of it.

Mr. BRODERICK. It appears from the data that we have been able to analyze so far, the photographic data and the onsite evaluation, that the fire-blocking layers on the seats reduced the amount of fire that occurred in those areas substantially. They are not designed to prevent burning over a 1½ hour fire, they are designed to work in the first 30, 60, or 90 seconds to provide a delay in the propagation of the fire and therefore flashover.

But in this particular accident, it's quite clear that they were of benefit in at least reducing, if not retarding, the amount of fire. That was very encouraging.

Admiral ENGEN. Thank you. I think I must try to get back to Mr. Carney's argument. I wish he were still here. There is so much value that's come from this. I know he knows that, because he said that in his statement. There is so much value that came from this thing, that we learned so much about seat blocking. We learned a great deal about exits. We learned a great deal about the forces.

The National Transportation Safety Board was able to come in afterward and inspect and look at crash analysis in concert with us. There is so much value there that this is what makes me feel very proud that we were able to do this.

Mr. PACKARD. I don't doubt that there was a great deal of value that came from the tests. Did you plan additional tests before this test was taken? Were there subsequent tests planned?

Admiral ENGEN. No, sir.

Mr. PACKARD. Are there now?

Admiral ENGEN. There are not at this time. And I would like to wait until all the data on the AMK has been reduced and we have had a chance to analyze that data before we would make any decision whether it would be worthwhile and what to do next.

Mr. PACKARD. Do you feel that there is any regulation or recommendation to the industry that should be made without further tests?

Admiral ENGEN. Yes. And they are ongoing, corroborated by the CID crash test. They were ongoing beforehand, and the CID corroborated those. Until all the data is reduced, I would like to respectfully hold my answer as to what is going to come specifically out of this crash, because we have a wealth of data that has to be reduced, and we really have to get into it and analyze it. But there is so much good there, and there is so much data which is bearing out hypotheses that I know we're going to come up with things.

Mr. PACKARD. Thank you, Mr. Chairman.

Mr. GLICKMAN. I just want to conclude again by talking about what specifically is going to be proposed now. You indicated whether it was a result of this test or corroborated therefrom, you're going to have new seat strength standards proposed in June. With respect to the antimisting fuel, nothing will be proposed right now. But would it be a fair statement to say that you haven't ruled out at any point in the future proposing rules on fuel additives?

Admiral ENGEN. I certainly would not want to rule out anything, Mr. Chairman. I think in research and development and engineer-

ing in aviation, we should keep our minds open, and I would like to keep looking.

Mr. GLICKMAN. Well, you see, I don't want to add \$3.5 billion or whatever you're talking about in terms of retrofitting all these airplanes, but on the other hand if you can come up with a fuel that can be utilized in existing aircraft without major retrofitting, I don't want to see you timid in approaching the industry about getting this done.

Admiral ENGEN. I will not be. And I don't want to commit myself, Mr. Chairman, to a firm course of action with respect to antimisting kerosene or other additives until I have had a chance to really look at this data and see exactly what we've got. But we won't stop. The point is we will continue to move forward, look, search, and try to improve.

Mr. PACKARD. Mr. Chairman.

Mr. GLICKMAN. Yes, go ahead.

Mr. PACKARD. Perhaps, if you would yield on that point, I think that was the thrust of my last question, was to try to determine in my own mind if some significantly costly recommendations and regulations could come from this one test without completely analyzing whether the test justifies such recommendations or regulations without further tests. That is the only concern I would have is that we would use this test, which in the minds of some may not be as conclusive as it is in the minds of others, that we would make firm and hard requirements on the industry that could be quite expensive that the tests may not totally bear out. I would want to make certain that those tests were very conclusive in those areas.

Admiral ENGEN. Thank you, Mr. Packard. Unequivocally, I agree with you, and we look at the cost-benefit analysis in everything that we do. We would not blindly march forward to implement something like that.

Mr. GLICKMAN. Just two more quick questions. I want to ask you a little bit about the flashover effect. How many additional seconds were given to the dummy passengers of the Boeing 720 by AMK over the conventional fuel? Do you have any idea on that one?

Admiral ENGEN. I don't. But let me ask Mr. Blake if he has any feel for that at all.

Mr. BLAKE. I don't think we have ever tried to assign a value to that. As you know, in looking at seat-blocking layers and looking at improved cabin materials, we have assigned a value of additional egress time due to those two additions. But we have not assigned a value to that.

Mr. GLICKMAN. What do you personally feel, Mr. Blake? Do you think that there was some additional time available to those dummy passengers as a result of the AMK that they would not have had had they had kerosene regular fuel on that plane?

Mr. BLAKE. Well, I think based on the tests that we showed you in the video, the skin of the airplane was sufficiently cool that even at the speed the aircraft was sliding out, the skin would not have melted and allowed the fire rapid access to the cabin. I think that's about the only conclusion that one could draw.

Mr. GLICKMAN. Which would have benefited, theoretically, the passengers inside.

Mr. BLAKE. Potentially, it was a benefit in that the fire would not have penetrated during slideout.

Mr. GLICKMAN. OK. A final question, Admiral Engen. Will the FAA propose, as the NTSB has recommended, the use of newer and better flight data recorders and cockpit voice recorders in airlines such as the ones tested in the crash test?

Admiral ENGEN. Last December we issued a notice of proposed rulemaking to improve the flight data recorders that Chairman Burnett has testified before you about, and that is ongoing at this point in time and we are upgrading the flight data recorders and cockpit voice recorders in the aircraft in the fleet.

Mr. GLICKMAN. OK. So the answer is basically yes then?

Admiral ENGEN. Yes.

Mr. GLICKMAN. OK. Thank you very much for excellent testimony and also for getting these films together.

Admiral ENGEN. Thank you, sir, very much.

Mr. GLICKMAN. We appreciate the work you're doing at the FAA.

Admiral ENGEN. We will keep charging. Thank you, sir.

[The prepared statement of Hon. Don Engen follows:]

STATEMENT OF THE HONORABLE DONALD D. ENGEN, FEDERAL AVIATION ADMINISTRATOR, BEFORE THE HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY, SUBCOMMITTEE ON TRANSPORTATION, AVIATION, AND MATERIALS, CONCERNING THE CONTROLLED IMPACT DEMONSTRATION, APRIL 2, 1985.

GOOD AFTERNOON MR. CHAIRMAN AND MEMBERS OF THE SUBCOMMITTEE. I AM PLEASED TO APPEAR BEFORE YOU TODAY TO DISCUSS THE CONTROLLED IMPACT DEMONSTRATION CONDUCTED BY THE FEDERAL AVIATION ADMINISTRATION (FAA) AND THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA) LAST DECEMBER. I AM ACCOMPANIED BY NEAL BLAKE, THE DEPUTY ASSOCIATE ADMINISTRATOR FOR ENGINEERING, AND TONY BRODERICK, THE ACTING ASSOCIATE ADMINISTRATOR FOR AVIATION STANDARDS. FOLLOWING MY TESTIMONY, DR. JOHN MARTIN, NASA ASSOCIATE ADMINISTRATOR FOR AERONAUTICS AND SPACE TECHNOLOGY, WILL DISCUSS THE NASA ACTIVITIES.

AS THE SUBCOMMITTEE IS AWARE, THE FAA HAS CONDUCTED A VARIETY OF PROGRAMS IN THE AIRCRAFT SAFETY AREA SINCE THE EARLY 1960'S. ONE KEY AREA IN WHICH WE HAVE CONDUCTED EXTENSIVE RESEARCH AND DEVELOPMENT WORK INVOLVES FIRE PROTECTION AND SUPPRESSION, SINCE FIRE IS A MAJOR THREAT TO PERSONS WHO OTHERWISE SURVIVE THE IMPACT OF A CRASH. IN 1979, TO OBTAIN THE VIEWS OF EXPERTS IN THIS AREA AND TO PROVIDE MORE DIRECTION TO OUR EFFORT, WE ESTABLISHED AN ADVISORY COMMITTEE (REFERRED TO AS THE SPECIAL AVIATION FIRE AND EXPLOSION REDUCTION COMMITTEE) TO EXAMINE THE ABILITY OF THE AIRCRAFT OCCUPANT TO SURVIVE IN AN AIRCRAFT FIRE ENVIRONMENT. IN 1980, WE FORMALIZED AN AIRCRAFT SAFETY PLAN, WHICH INCLUDED MANY OF THE RECOMMENDATIONS OF THAT COMMITTEE AND WAS KEYED TO PRODUCING A

NUMBER OF REGULATORY ACTIONS IN THE 1982-1985 TIME PERIOD. THE PLAN CALLED FOR WORK IN SIX MAJOR AREAS: CRASHWORTHINESS, ANTIMISTING KEROSENE, CABIN INTERIORS, A LARGE TRANSPORT CATEGORY AIRCRAFT CONTROLLED IMPACT DEMONSTRATION, EMERGENCY EVACUATION, AND AIRCRAFT SUPPORTING SYSTEMS.

TO SUPPLEMENT OUR PREVIOUS REPORTS TO YOU ON OUR AIRCRAFT SAFETY RESEARCH AND DEVELOPMENT EFFORTS, THIS AFTERNOON I WILL REPORT ON SOME OF THE PRELIMINARY RESULTS FROM OUR ANALYSIS OF THE CONTROLLED IMPACT DEMONSTRATION (CID) CONDUCTED ON DECEMBER 1, 1984. THE RESULTS ARE CONSIDERED PRELIMINARY BECAUSE NOT ALL OF THE RECORDED AND PHOTOGRAPHIC DATA HAVE BEEN ANALYZED.

THE OVERALL PURPOSE OF CID WAS TO VALIDATE TECHNOLOGY DEVELOPED TO IMPROVE TRANSPORT AIRCRAFT OCCUPANT SURVIVABILITY IN AN IMPACT SURVIVABLE ACCIDENT THROUGH REDUCED POST-CRASH FIRE HAZARD AND IMPROVED STRUCTURAL CRASH PROTECTION.

OTHER OBJECTIVES OF THE CID WERE TO DEMONSTRATE IMPROVED, CRASHWORTHY DESIGNED SEATS AND RESTRAINT SYSTEMS, AND TO ACQUIRE CRASH DATA ON A TRANSPORT AIRCRAFT UNDER CONTROLLED CONDITIONS. OUR PLAN HAS BEEN TO USE THESE DATA TO VERIFY AND IMPROVE COMPUTER MODELS THAT HAVE BEEN DEVELOPED TO PREDICT TRANSPORT AIRCRAFT STRUCTURAL CRASH BEHAVIOR.

THE AIRCRAFT USED IN THIS DEMONSTRATION WAS A BOEING 720, FOUR-ENGINE, INTERMEDIATE RANGE, JET TRANSPORT THAT ENTERED AIRLINE SERVICE IN THE MID-1960'S. ALTHOUGH THE BOEING 720 IS NOW CONSIDERED OBSOLETE, FOR THE PURPOSE OF THIS TEST, ITS STRUCTURAL DESIGN AND CONSTRUCTION WERE CONSIDERED TO BE SUFFICIENTLY SIMILAR TO BE REPRESENTATIVE OF TRANSPORT AIRCRAFT CURRENTLY USED BY DOMESTIC AND FOREIGN AIRLINES.

THE CID PROGRAM WAS A JOINT FAA/NASA RESEARCH AND DEVELOPMENT UNDERTAKING WITH SUPPORT FROM THE NATIONAL TRANSPORTATION SAFETY BOARD (NTSB), DEPARTMENT OF DEFENSE (DOD), INDUSTRY, AND THE BRITISH AND FRENCH GOVERNMENTS. JOINTLY FINANCED BY FAA AND NASA, THE CID REPRESENTS AN \$11.8 MILLION INVESTMENT IN AIR SAFETY. OF THIS AMOUNT, FAA EXPENDED \$8.1 MILLION AND NASA \$3.7 MILLION. FAA, THE OVERALL PROGRAM MANAGER, WAS RESPONSIBLE FOR THE ANTIMISTING FUEL EFFORT, THE CABIN FIRE SAFETY WORK, AND SOME OF THE STRUCTURAL CRASHWORTHINESS EXPERIMENTS. NASA DEVELOPED THE DATA ACQUISITION SYSTEM AND REMOTELY PILOTTED CONTROL SYSTEM (RPV) FOR THE AIRCRAFT, AND A NASA PILOT, USING THE RPV SYSTEM, FLEW THE AIRCRAFT INTO THE IMPACT SITE. IN ADDITION TO MANAGING THE FLIGHT PROGRAM, NASA HAD EXPERIMENTAL SEATS ABOARD THE AIRCRAFT AND CURRENTLY IS ANALYZING THE EFFECTS OF THE IMPACT FORCES ON THE STRUCTURE.

THE CID SCENARIO WAS DESIGNED TO BE REPRESENTATIVE OF AN "IMPACT-SURVIVABLE" ACCIDENT. BY THIS, WE MEAN AN AIRCRAFT ACCIDENT IN WHICH THE FUSELAGE MAINTAINS HABITABLE SPACE AND SOME PASSENGERS AND CREW WOULD BE ABLE TO SURVIVE THE CRASH IMPACT FORCES.

FOLLOWING IMPACT, THE AIRCRAFT WAS TO SLIDE OUT OVER A PACKED STONE BED THAT WAS BUILT TO PROVIDE A FRICTION IGNITION SOURCE FOR THE FUEL. THE PREPARED IMPACT SITE ALSO HAD EIGHT HEAVY STEEL STRUCTURES BOLTED TO CONCRETE FOUNDATIONS THAT WERE DESIGNED TO OPEN THE WING FUEL TANKS TO INSURE FUEL SPILLS OF 20 TO 100 GALLONS PER SECOND. OPERATING APPROACH LIGHTS WERE ALSO INSTALLED IN THE SLIDEOUT AREA TO SERVE AS IGNITION SOURCES. THE AIRCRAFT WAS FITTED WITH TWO JET FUELED FLAME GENERATORS IN THE TAIL CONE TO PROVIDE AN ADDITIONAL AND POSITIVE IGNITION SOURCE.

INSIDE THE AIRCRAFT THERE WERE 73 DUMMIES, OF WHICH 13 WERE INSTRUMENTED ANTHROPOMORPHIC DUMMIES WHICH HAVE SIMILAR CHARACTERISTICS TO HUMAN BODIES IN REGARD TO RESPONSE TO IMPACT FORCES. THESE 13, INCLUDING THE PILOT DUMMY, WERE FITTED WITH ACCELEROMETERS INSTALLED IN THE HEAD, THORAX, AND PELVIC AREAS TO MEASURE IMPACT FORCES. LOAD CELLS WERE INSTALLED TO MEASURE THE FORCES ON THE LAP BELTS AND SHOULDER HARNESSSES. THE SEATS OCCUPIED BY THESE INSTRUMENTED DUMMIES WERE ALSO EQUIPPED WITH MULTIPLE SENSORS TO MEASURE IMPACT AND SLIDEOUT FORCES. OTHER FORCE SENSORS WERE INSTALLED AT 175 LOCATIONS IN THE WINGS, FUSELAGE, FLOOR, GALLEY, AND OVERHEAD STOWAGE COMPARTMENT. DATA FROM THESE SENSORS WERE RECORDED ONBOARD AND TELEMETERED TO GROUND RECORDERS.

THE CID AIRCRAFT ALSO CARRIED 11 HIGH-SPEED MOTION PICTURE CAMERAS INSIDE THE CABIN, ONE HIGH-SPEED MOTION PICTURE CAMERA MOUNTED ATOP THE VERTICAL STABILIZER, AND ONE MOTION PICTURE AND TWO VIDEO

CAMERAS MOUNTED IN THE NOSE. THE NOSE VIDEO CAMERAS WERE DESIGNED PRIMARILY TO AID THE PILOT IN THE REMOTE OPERATION OF THE AIRCRAFT. ADDITIONAL PHOTOGRAPHIC COVERAGE WAS PROVIDED BY APPROXIMATELY 100 FIXED AND REMOTELY CONTROLLED CAMERAS POSITIONED AROUND THE IMPACT SITE. TWO HELICOPTERS AND A NAVY P-3 PHOTO AIRPLANE EQUIPPED WITH SPECIAL LONG-RANGE, HIGH-SPEED CAMERAS PROVIDED AERIAL PHOTOGRAPHIC COVERAGE.

THE B-720 WAS FUELED WITH 11,325 GALLONS OF INLINE BLENDED ANTIMISTING KEROSENE (AMK). TESTS SHOWED THE FUEL WAS OF HIGH QUALITY AND HAD THE DESIRED FLAMMABILITY RESISTANCE. THE ENGINES WERE STARTED AND OPERATED NORMALLY ON AMK THROUGHOUT THE 40 MINUTES OF PREFLIGHT CHECKS.

AT 9:13 A.M. ON DECEMBER 1, THE CID AIRCRAFT TOOK OFF FROM EDWARDS AIR FORCE BASE, CALIFORNIA, FOR ITS REMOTELY PILOTED FINAL FLIGHT. WEATHER CONDITIONS WERE IDEAL. VISIBILITY WAS EXCELLENT, AND THE WIND SPEED WAS LESS THAN 5 KNOTS. THE AIRCRAFT WAS CLIMBED TO 2,300 FEET ABOVE GROUND LEVEL AND FLOWN ALONG A PREDETERMINED FLIGHT PATH TO INTERCEPT A SIMULATED INSTRUMENT LANDING SYSTEM TO BEGIN ITS DESCENT. APPROACH SPEED WAS 150 KNOTS, AND THE SINK RATE WAS WITHIN THE TARGETED RANGE. A 150-FOOT DECISION HEIGHT WAS SET, BELOW WHICH THERE WOULD BE NO ABORT. WHEN PASSING THIS DECISION HEIGHT, THE AIRCRAFT WAS SLIGHTLY BELOW THE GLIDESLOPE AND TO THE RIGHT OF THE DESIRED PATH. THE PILOT TOOK APPROPRIATE CORRECTIVE ACTIONS, WHICH RESULTED IN A ~~MILD~~ ROLL OSCILLATION.

AT 9:22:11 A.M., THE AIRCRAFT'S LEFT OUTBOARD ENGINE IMPACTED THE GROUND. THE AIRCRAFT WAS IN A SLIGHTLY NOSE-DOWN/LEFT WING DOWN ATTITUDE WITH WHEELS RETRACTED AND WING FLAPS DEPLOYED AT 30 DEGREES. INITIAL GROUND CONTACT OF THE LEFT OUTBOARD ENGINE WAS APPROXIMATELY 300 FEET SHORT OF THE TARGET AREA, WITH THE AIRCRAFT IN A SLIGHT YAW TO THE LEFT. THE LEFT INBOARD ENGINE THEN CONTACTED THE GROUND FOLLOWED BY THE INITIAL FUSELAGE IMPACT.

DURING SLIDEOUT, THE AIRCRAFT CONTINUED TO YAW TO THE LEFT AND CAME INTO CONTACT WITH THE FIRST OF THE STEEL WING OPENING STRUCTURES AT A YAW ANGLE OF 38 DEGREES. INITIAL CONTACT WAS WITH THE NEXT TO THE OUTERMOST OF THE FOUR WING OPENERS ON THE RIGHT SIDE.

THE CUTTER ENTERED AND PASSED THROUGH THE RIGHT INBOARD ENGINE. IT THEN HIT THE LEADING EDGE OF THE WING AND DIAGONALLY SLASHED OPEN THE LOWER WING SKIN BACK TO THE VICINITY OF THE MID-CHORD, LEADING TO THE FAILURE AND SEPARATION OF THE RIGHT WING. FOLLOWING CONTACT OF THE CUTTER WITH THE ENGINE, THERE APPEARED TO BE IMMEDIATE IGNITION OF ENGINE FLUIDS INCLUDING DEGRADED AMK, ENGINE OIL, AND HYDRAULIC FLUID. THE FIRE THAT RESULTED CONTINUED THROUGHOUT THE AIRCRAFT SLIDEOUT WITH THE ENGINE ACTING AS THE MAIN FLAME HOLDER OR ATTACHMENT POINT. THE INTENSITY OF THE FIRE APPEARS TO HAVE BEEN CAUSED AT LEAST IN PART BY THE CONTINUED FLOW OF FUEL UNDER PRESSURE, POSSIBLY FROM RUPTURED FUEL LINES, DIRECTLY ONTO THE HOT ENGINE SURFACES. THIS INTENSE FIRE OCCURRED IN THE IMMEDIATE AREA WHERE THE WING TANKS HAD BEEN OPENED AND RESULTED IN VAPORIZATION

AND IGNITION OF THE FUEL VAPORS BEFORE MUCH ANTIMISTING ACTION HAD OCCURRED. THIS WAS IN PART DUE TO THE FACT THAT THE AIRCRAFT WAS YAWED TO THE LEFT SUCH THAT THE ENGINE BLOCKED AIR FLOW INTO THE AREA OF GREATEST FUEL RELEASE. THIS IN TURN INHIBITED THE DESIRED ANTIMISTING ACTION OF THE AMK FUEL AND INCREASED THE EXPOSURE TIME OF THE FUEL TO THE INTENSE IGNITION SOURCE. THE RESULTING FLAME PASSED OVER THE RIGHT SIDE OF THE FUSELAGE AS THE AIRCRAFT CONTINUED TO YAW TO THE LEFT. THE FUSELAGE APPEARED TO BE ENGULFED IN FLAME FOR APPROXIMATELY 9 SECONDS, AND PHOTOGRAPHIC EVIDENCE REVEALED ONLY RELATIVELY MINOR DAMAGE TO THE EXTERIOR OF THE FUSELAGE DUE TO THE SHORT EXPOSURE TIME AND THE REDUCED HEAT TRANSFER TO THE CABIN SKIN WHICH IS CHARACTERISTIC OF AMK. THE INSTRUMENTATION STRIPES PAINTED ON THE FUSELAGE REMAINED VISIBLE AND DISTINCT.

A SECOND CUTTER STRUCK THE RIGHT INBOARD WING LEADING EDGE FLAP AND SLASHED DIAGONALLY THROUGH THE LOWER WING SKIN TO THE RIGHT MAIN GEAR WHEEL WELL. PART OF THE CUTTER BROKE OFF AND ENDED UP IN THE LOWER AFT CARGO COMPARTMENT.

ANOTHER CUTTER STRUCK THE LEADING EDGE OF THE RIGHT WING AND SLASHED DIAGONALLY TO THE REAR. IT PASSED THROUGH THE LOWER CENTER WING BOX SECTION AND PENETRATED THE LEFT MAIN GEAR WHEEL WELL, THUS PERMITTING THE BURNING FUEL TO ENTER THE FUSELAGE FROM THE BOTTOM. FUEL ALSO ENTERED THE AIRCRAFT THROUGH THE FORWARD RIGHT CARGO DOOR WHICH HAD OPENED ON IMPACT.

THE CUTTER ON THE FAR RIGHT PASSED THROUGH THE TRAILING EDGE OF THE INBOARD RIGHT WING FLAP SEGMENT AND THEN SLICED DIAGONALLY THROUGH THE LOWER AFT FUSELAGE, THEREBY PROVIDING AN ADDITIONAL OPENING THROUGH WHICH FUEL COULD ENTER THE FUSELAGE.

AT 9:22:21 A.M., THE CID AIRCRAFT CAME TO REST. WITHIN 2 MINUTES THE EDWARDS AFB FIRE DEPARTMENT WAS ON THE SCENE. THE EXTERNAL FIRE WAS RAPIDLY EXTINGUISHED, USING STANDARD CRASH-FIRE-RESCUE PROCEDURES, AND THE CABIN ENTERED. THE PROCEDURES USED HAVE PROVEN EFFECTIVE IN MAXIMIZING PASSENGER PROTECTION DURING THE EVACUATION AND RESCUE ACTIVITIES. HOWEVER, IN THE CASE OF CID, AN UNDETECTED FIRE IN THE BAGGAGE COMPARTMENT DEVELOPED RAPIDLY. THIS FIRE ESCAPED DETECTION INITIALLY DUE TO THE INTENSE SMOKE FROM THE EXTERNAL FIRE PRIOR TO ITS EXTINGUISHMENT. THE EVENTS THAT LED UP TO THIS FIRE WERE SOMEWHAT UNIQUE, IN THAT THE WING CUTTERS OPENED THE FUSELAGE, SEVERED THE RIGHT WING TANKS, AND THE AIRCRAFT THEN YAWED IN A MANNER THAT INTRODUCED FUEL DIRECTLY INTO THE LOWER PORTION OF THE FUSELAGE. EARLIER DETECTION OF THE BAGGAGE COMPARTMENT FIRE WOULD POSSIBLY HAVE RESULTED IN EARLIER CONTROL AND EXTINGUISHMENT WHICH, IN TURN, WOULD HAVE PRESERVED MORE OF THE AIRCRAFT INTERIOR FOR SUBSEQUENT DETAILED ANALYSIS.

SINCE THE ENTIRE FIRE SEQUENCE WAS DOCUMENTED ON FILM AND VIDEO TAPE, WE BELIEVE THAT THIS MATERIAL WILL BE EXTREMELY VALUABLE AS A TRAINING AID IN POST-CRASH FIRE FIGHTING.

I WOULD LIKE NOW TO REVIEW BOTH THE OBJECTIVES AND THE ACTUAL ACCOMPLISHMENTS OF THE THREE MAJOR PROGRAM ELEMENTS OF THE CID:

1. CRASHWORTHINESS/CRASH BEHAVIOR
2. ANTIMISTING FUEL PERFORMANCE AND BEHAVIOR
3. CABIN FIRE SAFETY/EGRESS POTENTIAL

THE MAJOR ELEMENTS OF THE CRASHWORTHINESS AND CRASH BEHAVIOR PORTION OF THE CID WERE DESIGNED TO:

- DETERMINE CRASH IMPACT FORCES AND THE TRANSMISSION AND ATTENUATION OF THE FORCES THROUGH THE FUSELAGE STRUCTURE, THE FLOOR, AND THE SEAT TO THE OCCUPANT.
- EVALUATE THE FUSELAGE AND AIRCRAFT STRUCTURAL RESPONSE AND INTEGRITY IN A CRASH ENVIRONMENT.
- VALIDATE MODELS USED TO PREDICT STRUCTURAL RESPONSE IN A CRASH ENVIRONMENT.
- DETERMINE THE PERFORMANCE OF EXISTING AND ADVANCED ENERGY ABSORBING SEATS AND RESTRAINT SYSTEMS IN A SURVIVABLE IMPACT.
- EVALUATE THE PERFORMANCE OF NEW DIGITAL FLIGHT DATA RECORDERS AND COCKPIT VOICE RECORDERS.

- EVALUATE THE ADEQUACY OF HAZARDOUS MATERIAL CONTAINERS CARRIED AS CARGO ONBOARD THE AIRCRAFT.
- EVALUATE THE PERFORMANCE OF OVERHEAD STORAGE BINS AND GALLEYS.

THE IMPACT SCENARIO WAS SELECTED TO BE REPRESENTATIVE OF AN ACCIDENT OCCURRING ON FINAL APPROACH OR SHORTLY AFTER TAKEOFF. THE CHARACTERISTICS OF THE SCENARIO WERE DERIVED FROM A STUDY OF PAST IMPACT-SURVIVABLE ACCIDENTS. THESE INCLUDED: A DESCENT RATE OF 17 FEET PER SECOND, A TRUE AIRSPEED OF 150 KNOTS, A SLIGHTLY NOSE-UP ATTITUDE, AND MINIMUM ROLL AND YAW.

TO VERIFY THAT A DESCENT RATE OF 17 FEET PER SECOND WOULD NOT RESULT IN LOSS OF INTEGRITY OF THE FUSELAGE STRUCTURE, FAA CONDUCTED A NUMBER OF DROP TESTS INVOLVING SECTIONS OF BOTH WIDE AND NARROW BODY AIRCRAFT, AS WELL AS A DROP TEST INVOLVING A COMPLETE B-707 AIRCRAFT. THESE DROP TESTS INDICATED THAT THE AIRCRAFT FUSELAGE WOULD REMAIN INTACT WITH ONLY MINOR WARPAGE OF THE FUSELAGE AND LOCALIZED MINOR DEFORMATION OF THE FLOOR STRUCTURE OCCURRING IN THE VICINITY OF SEVERAL BULKHEADS. THE TESTS ALSO INDICATED THAT THE VERTICAL LOADS TRANSMITTED THROUGH THE STRUCTURE TO THE SEAT OCCUPANTS REMAINED WITHIN THE SURVIVABLE RANGE OF HUMAN IMPACT TOLERANCE.

IN THE CID EVENT, THE INITIAL IMPACT FORCES WERE MEASURED AS THE LEFT OUTBOARD ENGINE, LEFT INBOARD ENGINE, AND THE FUSELAGE TOUCHED DOWN IN SEQUENCE. THE INITIAL IMPACT OF THE FUSELAGE WAS IN THE

FORWARD AREA OF THE CABIN. THE DATA ON THE IMPACT FORCE MAGNITUDE AND PULSE SHAPE AND THE ATTENUATION OF THAT FORCE BY THE FUSELAGE AND SEATS WAS MEASURED AT A NUMBER OF LOCATIONS IN THE FUSELAGE. AS ONE WOULD EXPECT, THE IMPACT FORCES WERE HIGHEST IN THE FORWARD CABIN AREA AND ALSO IN THE COCKPIT. THESE INITIAL FORCES, AS MEASURED IN THE INSTRUMENTED DUMMIES, WERE ALL WITHIN THE ENVELOPE OF HUMAN TOLERANCE. SEAT AND RESTRAINT SYSTEMS REMAINED IN PLACE. IMPACT LOADS WERE SUCH THAT THE ENERGY ABSORBING SEATS SHOWED LITTLE "STROKING," INDICATING THAT THESE SEATS WERE CAPABLE OF ABSORBING HIGHER IMPACT LOADS.

SHORTLY AFTER THE INITIAL IMPACT, THE AIRCRAFT ENCOUNTERED THE WING CUTTERS IN A YAWED CONDITION WHICH PLACED HIGH LATERAL AND LONGITUDINAL LOADS ON THE FUSELAGE, SEATS, AND RESTRAINT SYSTEMS. THIS IMPACT APPEARED, IN LARGE MEASURE, TO CAUSE A FUSELAGE AND FLOOR RUPTURE ON THE LEFT SIDE OF THE AIRCRAFT JUST AFT OF THE WING BOX. THIS WAS DUE PRIMARILY TO THE PASSAGE OF ONE OF THE WING CUTTERS THROUGH THE FUSELAGE WHICH RESULTED IN DESTRUCTION OF THE AIRCRAFT MAIN STRUCTURAL MEMBER CALLED THE KEEL BEAM. THIS DESTRUCTION OF THE AIRCRAFT STRUCTURE IN THE WING BOX AREA SUBSTANTIALLY WEAKENED THE FUSELAGE. DESPITE THE DAMAGE INFLECTED BY THIS AND SEVERAL OTHER CUTTERS, THE FUSELAGE REMAINED ESSENTIALLY INTACT AND PROVIDED A HABITABLE SPACE FOR THE OCCUPANTS.

THE SECOND IMPACT ALSO APPEARED TO HAVE CAUSED THE FAILURE OF THE LATERAL BRACING ON SEVERAL SEATS. DESPITE THESE FAILURES, THE SEATS REMAINED IN PLACE AND PROTECTED THE OCCUPANTS.

IN THE AREA OF THE FUSELAGE BREAK, THE FLOOR SEPARATED AND A DISPLACEMENT OF OVER 1 FOOT OCCURRED. THIS RESULTED IN RELEASE AND FAILURE OF THE OUTBOARD ATTACHMENT FITTINGS ON ONE ROW OF SEATS. THE LATERAL FORCES, RESULTING FROM STRIKING THE WING CUTTERS IN A YAWED POSITION, CAUSED THE SEAT TO ROTATE INTO THE AISLE. RELEASE OF A SEAT IS TO BE EXPECTED WHEN SEVERE FLOOR TRACK DEFORMATION OR BREAKAGE OCCURS.

NASA HAD POSITIONED TWO OF ITS ANTHROPOMORPHIC DUMMIES IN THE BRACED POSITION, AND THESE DUMMIES DID NOT APPEAR TO HAVE BEEN MOVED SIGNIFICANTLY BY THE IMPACT FORCES. OTHER DUMMIES, SEATED UPRIGHT, DID MOVE DURING IMPACT AND SLIDEOUT. THE ROW OF SEATS PROVIDED BY THE FRENCH GOVERNMENT, WHICH WAS INSTALLED IN THE AFT END OF THE AIRCRAFT ON THE LEFT, REMAINED IN PLACE BUT WAS SUBSEQUENTLY CONSUMED BY FIRE.

AS PART OF THE C-130 CRASHWORTHINESS EVALUATION EXPERIMENTS, TWO OVERHEAD STORAGE COMPARTMENTS WERE INSTRUMENTED. WHILE THE OVERHEAD COMPARTMENTS OPENED DURING THE IMPACT, THE COMPARTMENTS AND GALLEYS REMAINED IN PLACE. THE CARRYING OF HEAVY ITEMS IN AIRLINE OVERHEAD COMPARTMENTS IS OF GREAT CONCERN TO ME, AND WE ARE TAKING STEPS TO FURTHER DEFINE WHAT CAN BE CARRIED IN THESE COMPARTMENTS.

THE IMPACT FORCE MAGNITUDE AND SHAPE MEASURED AT VARIOUS POINTS IN THE FUSELAGE WERE IN CLOSE AGREEMENT WITH SIMILAR DATA RECORDED IN THE DROP TESTS. THE CID DATA WILL BE USED TO CALIBRATE AND TO VALIDATE ANALYTICAL MODELS USED TO PREDICT STRUCTURAL RESPONSE IN A CRASH SCENARIO.

THE NEW DIGITAL FLIGHT DATA RECORDERS (FDR) AND COCKPIT VOICE RECORDERS (CVR) WERE REMOVED FROM THE AIRCRAFT AND THE DATA ARE BEING EVALUATED. ALL UNITS APPEARED TO OPERATE NORMALLY. SINCE THE AIRCRAFT WAS HEAVILY INSTRUMENTED, IT WILL BE POSSIBLE TO EVALUATE THE ADEQUACY OF THE FDR INFORMATION FOR ACCIDENT INVESTIGATION.

THE HAZARDOUS MATERIAL CONTAINERS APPEARED TO PROVIDE THE DESIRED LEVEL OF PROTECTION.

ALL OBJECTIVES OF THE CRASHWORTHINESS PORTION OF THE CID WERE ACHIEVED.

THE MAJOR OBJECTIVE OF THE ANTIMISTING FUEL PERFORMANCE AND BEHAVIOR ELEMENT WAS TO DEMONSTRATE THAT USE OF AN ANTIMISTING ADDITIVE IN THE FUEL WOULD INHIBIT THE FORMATION OF A FINE FUEL MIST THROUGH WHICH FLAME COULD PROPAGATE BACK TO THE RUPTURED FUEL TANKS AND GENERATE A LARGE FIREBALL THAT COULD ENGULF THE AIRCRAFT AND, SUBSEQUENTLY, IGNITE SPILLED FUEL ON THE GROUND. PRIOR TO CID, THIS ANTIMISTING POTENTIAL HAD BEEN DEMONSTRATED IN OVER 300 WING SPILLAGE TESTS AT THE FAA TECHNICAL CENTER AND IN SIX CATAPULT CRASH

TESTS OF OBSOLETE MILITARY AIRCRAFT AT THE LAKEHURST NAVAL AIR ENGINEERING CENTER. THE CID WAS ALSO TO DEMONSTRATE THAT AMK IS COMPATIBLE WITH PROPULSION SYSTEMS AND, AFTER THE ANTIMISTING ADDITIVE IS DEGRADED, WILL BURN SATISFACTORILY IN A JET ENGINE COMBUSTOR DURING FLIGHT.

DESPITE THE FORMATION OF THE FUEL-FED FIRE, THERE IS PHOTOGRAPHIC EVIDENCE FROM THE TEST THAT SOME AMK FROM THE RUPTURED FUEL TANK ESCAPED THE FIRE IN THE DESIRED FORM OF LARGE DROPLETS.

THE ENGINES AND DEGRADERS OPERATED NORMALLY AND UNEVENTFULLY ON THE ANTIMISTING FUEL PRIOR TO AND DURING THE CID FLIGHT. ON THE DAY FOLLOWING THE IMPACT, FUEL SAMPLES WERE TAKEN FROM THE FUEL TANKS THAT HAD REMAINED INTACT. THESE FUEL SAMPLES WERE ANALYZED, AND ALL WERE NORMAL. ALL INDICATIONS SO FAR ARE THAT THE DEGRADED AMK IS FULLY COMPATIBLE WITH THE PROPULSION SYSTEM, CORROBORATING EARLIER GROUND AND FLIGHT TEST DATA.

TO SUMMARIZE THE ANTIMISTING FUEL PERFORMANCE AND BEHAVIOR ELEMENT OF THE CID, THE IMPACT SCENARIO WHICH OCCURRED AT EDWARDS AFB DEMONSTRATED THAT THERE ARE CONDITIONS WHERE ADDING AN ANTIMISTING CHARACTERISTIC TO JET FUEL IS NOT SUFFICIENT TO PREVENT A POST-CRASH FIRE. ONE EXAMPLE OF SUCH CONDITIONS, AS ILLUSTRATED BY THE CID, IS THE CASE WHERE THERE IS THE DESTRUCTION OF AN ENGINE AND THE RUPTURE OF FUEL LINES ON THE ENGINE PYLON WHICH PRODUCED AN INTENSE IGNITION

SOURCE NEAR THE LEADING EDGE OF THE WING AT THE POINT OF FUEL RELEASE. WHILE THE ANTIMISTING CHARACTERISTIC OF THE FUEL WOULD HAVE PREVENTED FORWARD PROPAGATION OF THE FIRE HAD THE FIRE SOURCE BEEN FARTHER AFT IN THE CID, IT PROVIDED LIMITED--ALTHOUGH STILL SIGNIFICANT--PROTECTION IN THE FOLLOWING RESPECTS. EXTERIOR AND INTERNAL FILM DOCUMENTATION INDICATES THAT THE RESULTANT FIREBALL DIMINISHED AFTER A PERIOD OF 9 SECONDS. EXAMINATION OF THE FILM FOOTAGE AND THE FUSELAGE INDICATES THAT THE FUSELAGE SUSTAINED RELATIVELY LITTLE DAMAGE DURING THE DURATION OF THE FIREBALL. THE REDUCED INTENSITY OF THE FIREBALL IS ATTRIBUTED TO THE ANTIMISTING CHARACTERISTICS OF THE FUEL. A FOLLOW-ON EVALUATION OF PREVIOUS ACCIDENTS IS BEING CONDUCTED TO DETERMINE THE PROBABILITY OF THIS TYPE ACCIDENT SCENARIO OCCURRING, BUT I HAVE LEARNED FROM YEARS OF CONDUCTING AVIATION ACCIDENT INVESTIGATIONS THAT YOU CANNOT PLAN A CRASH.

WITH REGARD TO CABIN FIRE SAFETY AND EGRESS POTENTIAL, EVEN THOUGH WE DID NOT EXPECT A MAJOR FIRE TO OCCUR, WE DECIDED TO TAKE ADVANTAGE OF THE OPPORTUNITY TO TEST SOME OF THE TECHNOLOGY THAT HAS EVOLVED FROM OUR CABIN FIRE SAFETY RESEARCH IN CASE THERE WAS SUCH A FIRE. WE INSTALLED FIRE BLOCKING LAYERS OVER THE CUSHIONS IN ALTERNATE ROWS OF SEATS. IN THOSE AREAS OF THE CABIN INTERIOR NOT ENTIRELY CONSUMED BY FLAME, THOSE SEATS WITH THE FIRE BLOCKING LAYERS SHOWED MUCH GREATER RESISTANCE TO HEAT AND BURNING THAN THE UNBLOCKED SEATS. MOREOVER, STRUCTURAL FIRE DAMAGE IN THE AREAS ABOVE AND ADJACENT TO BLOCKED SEATS WAS LESS SEVERE THAN IN THE AREAS OF THE UNBLOCKED SEATS.

ADVANCED MODIFIED EPOXY RESIN WINDOWS, WHICH PROVIDE ADDITIONAL TIME BEFORE BURN THROUGH, WERE INSTALLED ON THE CID AIRCRAFT IN ALTERNATE WINDOWS IN THE CABIN AREA BEHIND THE WING BOX. THESE WINDOWS ARE DESIGNED TO DELAY THE PENETRATION INTO THE CABIN OF AN EXTERNAL POOL FIRE. IN CID, FIRE PENETRATION WAS PRIMARILY THROUGH THE FLOOR. FOLLOWING THE FIRE, SEVERAL ADVANCED AND INTERSPERSED STANDARD PANES REMAINED IN PLACE ON BOTH SIDES OF THE AIRCRAFT IN THE REAR PART OF THE CABIN. DUE TO THE LENGTH AND INTENSITY OF THE FIRE, WE ARE UNABLE TO DRAW ANY CONCLUSIONS ON THE PERFORMANCE OF THE ADVANCED PANES.

NEW LOW-LEVEL, SELF-CONTAINED, EMERGENCY LIGHTS FOR FLOOR PROXIMITY ESCAPE PATH MARKING WERE INSTALLED ON EIGHT SEATS IN THE AIRCRAFT. THREE OF THE TRITIUM LIGHTS REMAINED BONDED TO SEATS WHICH SURVIVED THE FIRE. THE RAPID BUILDUP OF SMOKE IN THE CABIN, COMBINED WITH THE LOCATION OF THE CAMERAS HIGH IN THE CABIN, PREVENTED EVALUATION OF THE EFFECTIVENESS OF THESE LIGHTS.

WITH REGARD TO CABIN EGRESS, WE HAVE CONCLUDED THAT THE CID FLIGHT ENDED IN A SURVIVABLE IMPACT AND THE FUSELAGE, WHICH REMAINED ESSENTIALLY INTACT, PROVIDED THE OCCUPANTS WITH A HABITABLE POST-IMPACT SPACE.

MOREOVER, FOLLOWING THE IMPACT, HIGHLY EXPERIENCED ACCIDENT INVESTIGATORS FOUND THAT ALL THE EMERGENCY EXITS WERE STILL

OPERABLE; THAT IS, THEY OPENED EASILY. FLIGHT DECK ESCAPE WINDOWS WERE OPERABLE AND ESCAPE STRAPS WERE AVAILABLE FOR PILOT AND COPILOT LOCATIONS. THE FORWARD LEFT MAIN EXIT AND THE RIGHT REAR EXIT APPEARED TO BE SUFFICIENTLY CLEAR OF FLAMES THAT THEY COULD HAVE BEEN USED FOR PASSENGER EGRESS.

ANALYSIS OF PICTURES FROM HIGH-SPEED CAMERAS IN THE CABIN SHOW A RAPID BUILDUP OF SMOKE AFTER THE AIRCRAFT CAME TO A STOP WITH OBSCURATIONS OCCURRING IN UP TO 20 SECONDS AFTER SLIDEOUT DEPENDING ON THE AREA OF THE CABIN. THE SMOKE APPEARED TO COME FROM THE FUEL FIRE BENEATH THE CABIN FLOOR, ENTERING THE CABIN THROUGH HOLES IN THE FLOOR AND THROUGH VENTILATION GRILLS. ALTHOUGH WE CAN NEVER BE SURE, WE BELIEVE THAT "PASSENGERS" COULD HAVE ESCAPED, DEPENDING ON THEIR LOCATION RELATIVE TO THE USABLE EXITS.

AN ACCIDENT INVESTIGATION TEAM MADE UP OF FAA, NTSB, DOD, AND INDUSTRY CONDUCTED A POST-CRASH INVESTIGATION TO EVALUATE CURRENT INVESTIGATION TECHNIQUES. WHILE THE INVESTIGATION TEAM LEADER ARRIVED AT THE SCENE WITH THE FIRE-FIGHTING CREWS, THE REMAINDER OF THE TEAM ARRIVED SOMEWHAT LATER, AS THEY WOULD IN THE CASE OF A REAL ACCIDENT. THE INVESTIGATION INCLUDED A CAREFUL EXAMINATION OF THE WRECKAGE AND THE SITE. THE TEAM CONCLUDED THEIR INVESTIGATION IN 8 DAYS AND THEIR FINAL REPORT WILL BE AVAILABLE IN APRIL. THIS REPORT WILL INCLUDE AN EVALUATION OF CURRENT PROCEDURES. A PRELIMINARY ANALYSIS OF RESULTS SHOWS THAT THE INVESTIGATION METHODS USED TO RECONSTRUCT THE IMPACT CONDITIONS WERE ACCURATE AS VERIFIED BY THE FILM RECORDINGS.

WAS CID WORTH THE INVESTMENT? WE THINK IT WAS. IT PROVIDED EXTENSIVE IMPACT DATA AND INFORMATION ON THE RESPONSE OF AN AIRCRAFT STRUCTURE TO REAL CRASH IMPACT FORCES. IT ALSO HIGHLIGHTED THE FACT THAT ACCIDENT SCENARIOS ARE UNPREDICTABLE. IN THE CASE OF AMK, IT SHOWED THAT THERE ARE CONDITIONS WHERE AMK PROVIDES LITTLE PROTECTION.

THE EXTENSIVE DOCUMENTATION FROM THE INSTRUMENTATION AND CAMERA COVERAGE WILL PROVIDE INFORMATION TO SUPPORT FUTURE AIRCRAFT SAFETY ACTIVITIES.

IN SUMMARY:

- ALTHOUGH THE IMPACT SCENARIO DEVIATED FROM THE PLAN, THE TEST VALIDATED THAT THE PARAMETERS SELECTED FOR THE CRASH SCENARIO WOULD RESULT IN A SURVIVABLE IMPACT. IT FURTHER INDICATED THAT THE AIRFRAME DESIGNS IN CURRENT USE WOULD REMAIN ESSENTIALLY INTACT IN THIS TYPE OF IMPACT.
- OVER 97 PERCENT OF THE PHOTOGRAPHIC AND ELECTRONIC DATA RECORDERS WORKED SUCCESSFULLY. DATA ON THE STRUCTURAL RESPONSE OF THE FUSELAGE, WINGS, SEATS, RESTRAINT SYSTEMS, GALLEYS, AND OVERHEAD COMPARTMENTS WAS SUCCESSFULLY TELEMETERED BACK TO THE

GROUND STATION, AS WELL AS RECORDED ON BOARD THE AIRCRAFT. THE ONBOARD DATA ACQUISITION SYSTEMS SURVIVED THE IMPACT AND SUBSEQUENT FIRE. THE DATA, IN ADDITION TO CONFIRMING THAT THE CID WAS IMPACT SURVIVABLE, WILL BE USED TO VERIFY AND REFINED THE ANALYTICAL MODELS AND PROVIDE IMPACT FORCE CHARACTERISTICS FOR TESTING OF ADVANCED SEATS, RESTRAINT SYSTEMS, AND COMPOSITE STRUCTURES. THE MODELS, AS WELL AS CRASH SCENARIOS, WILL BE THE SUBJECT OF ADVISORY CIRCULARS TO BE ISSUED IN JUNE OF THIS YEAR.

- THE SEATS, EXCEPT FOR ONE AT THE FUSELAGE RUPTURE, REMAINED IN PLACE, AND THE RESTRAINT SYSTEMS RESTRAINED THE OCCUPANTS. A TRANSPORT SEAT STRENGTH NPRM IS PLANNED FOR ISSUANCE THIS JUNE.
- TESTS OF HAZARDOUS MATERIAL CONTAINERS, NEW FLIGHT DATA RECORDERS, AND COCKPIT VOICE RECORDERS SHOWED THAT THEY WERE CAPABLE OF SUCCESSFULLY PERFORMING THEIR INTENDED FUNCTIONS IN SUCH A CRASH SCENARIO.
- THE TEST, ALTHOUGH LIMITED IN EXTENT, DID DEMONSTRATE THE OPERATIONAL COMPATIBILITY OF AMK WITH AIRCRAFT AND ENGINE FUEL SYSTEMS AND THE TECHNICAL FEASIBILITY OF "DEGRADING" THE ANTIMISTING KEROSENE.

- IN ONE AREA, AMK FIRE PROTECTION, THE LOCATION OF THE FIRE SOURCE AT THE LEADING EDGE OF THE WING, PRECLUDED A DEMONSTRATION OF THE MAJOR ADVANTAGE OF AMK FUELS; NAMELY, THAT THE FORMATION OF LARGE FUEL DROPLETS PREVENTS THE FORWARD PROPAGATION OF A FIRE AND ATTACHMENT OF THE FIRE TO THE AIRCRAFT. THE USE OF THE ADDITIVE, HOWEVER, APPEARED TO REDUCE THE HEAT TRANSMITTED TO THE FUSELAGE BY THE FIREBALL.
- THERE WAS EVIDENCE THAT THE SEAT CUSHION FIRE-BLOCKING LAYERS, WHICH WILL BE REQUIRED PURSUANT TO A NEW FAA RULE, DELAYED THE SPREAD OF INTERNAL FLAMES.

BASED ON THE PRELIMINARY RESULTS AVAILABLE FROM CID, I AM PROCEEDING WITH ALL OF OUR ANTICIPATED RULEMAKING ACTIONS, EXCEPT THAT WITH RESPECT TO AMK. WE WILL WAIT FOR THE COMPLETE ANALYSIS OF CID DATA BEFORE DECIDING ON FURTHER ACTION IN THIS AREA.

THE VIDEO YOU ARE ABOUT TO SEE WILL COVER MOST OF THE POINTS I HAVE ADDRESSED. I BELIEVE THAT IT WILL PROVIDE YOU WITH A REALISTIC ILLUSTRATION OF WHAT ACTUALLY TOOK PLACE ON DECEMBER 1 AT EDWARDS AIR FORCE BASE.

WHEN THE VIDEO PRESENTATION IS COMPLETE, MY ASSOCIATES AND I WOULD BE PLEASED TO RESPOND TO ANY QUESTIONS YOU MAY HAVE.

Mr. GLICKMAN. Our next witness is Dr. John Martin, Associate Administrator at NASA, a frequent visitor to this committee.

Dr. Martin, I understand that Fitz Fulton, the pilot who flew the plane, is here with you?

Mr. MARTIN. Yes, Mr. Chairman.

Mr. GLICKMAN. Why don't you turn your mike on.

Mr. MARTIN. Yes, Mr. Chairman, he is, along with Mr. Samuel Venneri, also of NASA, who might help me to answer questions.

Mr. GLICKMAN: OK. I understand that Mr. Fulton has been an active test pilot for some 30 years both with the Air Force and at NASA.

Is that correct? And that you had something to do with Scott Crossfield's career. I don't know if that's good or bad, Mr. Fulton. But he's down there.

Mr. FULTON. Only the good parts.

Mr. GLICKMAN. I understand you have the longest record of duty of any pilot at Edwards Air Force Base. So we appreciate your being here.

You may proceed, Dr. Martin. Your entire statement will appear in the record, so you may summarize if you desire.

**STATEMENT OF DR. JOHN MARTIN, ASSOCIATE ADMINISTRATOR
FOR AERONAUTICS AND SPACE ADMINISTRATION, ACCOMPANIED BY SAMUEL VENNERI; RICHARD TOBIASON; AND FITZ-HUGH FULTON**

Dr. MARTIN. Thank you. I will take a few minutes to do so, Mr. Chairman. Admiral Engen has very generously referred a couple of times to NASA's performance in the CID, and I would like just to take, as I said, a few minutes to outline what that activity was.

We have been in the crash impact business for a number of years, since 1972, when we began full-scale general aviation testing after impact and analysis of those data, so that the opportunity to participate in CID was an important opportunity for us and we were very pleased to work with the FAA in doing so.

Our responsibilities in the CID were to design the experiment, to prepare the aircraft, and to carry out the test, which we did on December 1. Designing the experiment consisted of devising a data acquisition system, getting the cameras, accelerometers, and the like, working together, which we did, carrying out some drop tests of fuselage sections to assure what the proper sink rate should be and preparing the aircraft by getting the RPV system working. You heard that it was the largest aircraft ever remotely piloted in that way. We carried out 14 test flights to be sure we were ready.

Many of the tests were necessary because the aircraft was so old that different things kept going wrong. But we finally got that worked out. And as I said, we carried out the test on December 1.

The execution of the controlled impact demonstration was very close to perfect. We were right on the centerline of the box we were supposed to come down in. The longitudinal position error was 285 feet short. That's about 1.1 seconds, to give you some idea of how fast the reaction needed to be.

The sink rate of the aircraft was right on the money, and so was the forward speed, being, respectively, 17 feet a second and 151

knots. Everything worked as far as instrumentation is concerned. And of the cameras, 10 out of 10 worked. And of the accelerometers, 97 percent were active at impact.

The data from the experiment are incomplete at this time. There is a large amount of dynamic data, which is time-varying data, which we are in the process of analyzing at the present time. There are some indications of the severity or some measures of the impact, however. The fuselage bottom—that is to say, that part which made the initial impact—suffered 32 G's. At the same time that the 32 G's taking place, the subfloors experienced 7 G's and the passenger deck 7 G's also.

The longitudinal loads were less than that. The highest loading was in the forward cabin, where there were 14 G's longitudinal and in the rest of the cabin it was as low as 4 G's. The lateral loads—that is to say, the cross-range, the side-to-side G loads—were somewhere between 2 and 5 G's, being higher forward and lesser aft. The vertical loads were in the range of 7 to 15 G's, again being higher in the forward end of the aircraft and lesser in the aft portion of the aircraft.

Based on the forces and the accelerations that were involved, the impact was survivable. And that is not to start again the argument about the AMK.

The future work that we have to do consists of the data reduction of, as I said, what is a great amount of data. We expect to have the data reduction carried out by August 1985. After that we will compare tests and analysis to make sure that we do have a thorough and full understanding of what took place structurally and dynamically.

We will carry out parametric studies and, in the process, improve the data base of dynamic analysis problems. And that will probably be finished by just about a year from now, maybe February 1986.

The payoff, as far as NASA is concerned, for the controlled impact demonstration is better structural modeling, better analytical methods, and more detailed analyses of airframes, which will give rise to more efficient designs and finally, in the ultimate end, safer flight for the American public.

Mr. Chairman, I want to thank the subcommittee for permitting us to summarize what NASA's role was in the CID. I must say that working with the FAA was a pleasant experience and we would do it again. Thank you very much.

Mr. GLICKMAN. Thank you. Dr. Martin, what new knowledge has been gained with regard to the G forces that the human body can tolerate in a crash?

Dr. MARTIN. I would say that as far as we've gone so far, Mr. Chairman, there is no new information on that. I think that the G levels were at or below the levels that have been stressed before. So that I think that there was no new knowledge in that respect.

Mr. GLICKMAN. I wonder if we could ask the pilot a couple of questions.

Dr. MARTIN. Certainly.

Fitz, why don't you come to the table, and Sam.

This is Mr. Fitzhugh Fulton, Mr. Chairman.

Mr. GLICKMAN. I wonder if you might tell us, first of all, when you crashed this plane, did it do as you had expected it to do, or specifically what didn't it do on landing that you would have liked to have seen done?

Mr. FULTON. Well, obviously I think we would like to have seen it hit exactly wings level, exactly down the center line. But it didn't hit exactly that way. I think sometimes when you prejudge a test program, you make a mistake because you're going to be disappointed sometimes. But you do the best you can to bring it down the center, in this case, which was the objective. But, we had a lot of work to preplan the test. The airplane performed exactly as we hoped it would, flying around the track. We had had some problems with some of the guidance in some of the earlier tests, and we worked on those. But we were very, very aware that this was an old airplane and even though we put a lot of technology into it to make it work, that we could have a failure flying around the track and we might lose the airplane, lose the complete test.

So, my intention was to touch it down on the first attempt if at all possible, and even though it did touch down in a slightly wing-down attitude, I was pleased that we touched down as close to the spot as we had planned to. You always like to do things perfect and you like to have it exactly wings level, but it didn't work out that way. But, it was close enough to all the parameters that I was pleased with the way it went.

Mr. GLICKMAN. So you could have taken it back around if you weren't pretty well centered?

Mr. FULTON. That's correct. At one point. Now, once we reached 150 feet, our ground rules were that we must continue, and there was no go-around below 150 feet. Now, the little oscillation that we picked up did not occur until just about the 150-foot point. And that was in making a correction toward the center line.

This was a correction we had done many times on the simulator, but we really could not make that practice in flight. You see, with a safety crew on board, we never flew below 150 feet. So the last part, which is a critical part, was never practiced except on a simulator.

Mr. GLICKMAN. Tell me, did we learn anything about remote guidance of aircraft that might be useful either in the commercial or the military side of the picture as a result of this test?

Mr. FULTON. Well, I am not sure what the transfer is on remote guidance. I think we at NASA have a reasonable amount of experience in remote-guided program. We have had several others in the past which we've been successful on. And I think this is from our standpoint just an extension of that knowledge. We certainly gain knowledge when we're handling a large airplane that we did not have before. And I suppose if we were doing it over again, we might want to do it with twice the money and a more sophisticated airplane. But considering the fact that we were using an old airplane and we're trying to keep the costs down and yet get successful results, I think we did about as well as we could hope to.

Mr. GLICKMAN. Now, when this plane crashed, what percentage of fuel was it loaded up to?

Mr. FULTON. Well, at takeoff it was completely full of fuel. So it was loaded up to its maximum gross weight for that model air-

plane, a little over 200,000 pounds. And the fuel used was only what it took to start the engines and take off and go around the pattern, you know, 10 minutes of flying.

Mr. GLICKMAN. So it was substantially full then?

Mr. FULTON. Yes.

Mr. GLICKMAN. If you had to gauge the success or failure of this crash, a lot of that may be related, you know, to how most planes would crash in which you might have a survivable type of crash. Are we talking about situations where landing gears don't go down? What kind of scenario do you see where most crashes are survivable? On takeoff where you have a failure and they have to bring the plane to a stop? What I am trying to figure out is what percentage of situations where you have fatal accidents might there be a situation where you have a survivable, potentially survivable, situation?

Mr. FULTON. Well, of course obviously, FAA has more access to statistics like this.

Mr. GLICKMAN. As a pilot you know—

Mr. FULTON. Just my experience as a pilot, you know, the takeoff scenario is certainly one where you could go in and it could be survivable. Another, I think, probably more realistic, is one where you're maneuvering toward the airport, as an example, an airplane that hits a hill 8 or 10 miles out from the airport due to either weather or the terrain being higher than they expected. So those kinds of things where the unexpected contact with the ground, without any warning, I think there are oftentimes some survivors on those kind of things.

Mr. GLICKMAN. OK. Thank you.

Mr. Lewis.

Mr. FULTON. I might just comment, getting into the FAA's business a little bit, that survivability, I think that survivability is only for the quick, you know, whether this accident was survivable or not, those that sat around for 60 seconds and wondered what was going on, probably weren't going to survive, but those who were quick in the first 15 or 20 seconds got moving. Some probably would get out.

Mr. GLICKMAN. Yes. I guess the question we ask is would more have gotten out in this scenario than if you would have had normal fuel.

Mr. FULTON. I will let them judge that.

Mr. GLICKMAN. Yes. OK.

Mr. Lewis.

Mr. LEWIS. Yes. That is the question that I wanted to pursue a little bit where I had asked about the flash fire in the cabin and things of that nature. I guess I am confused with the AMK fuel. It would seem to me that the airplane could crash, the ball of fire easily goes with them; they don't fly through it or slide through it. And in most cases, with the standard types of fuel, by sliding that plane down the runway, your fuselage starts to disintegrate because of tremendous heat and melt and that sort of thing.

Do you feel that, with the AMK fuel, this would have been prevented to some degree?

Dr. MARTIN. Mr. Lewis, I am going to interject before Fitz answers. The AMK part of the test is all FAA's and NASA has—

plane, a little over 200,000 pounds. And the fuel used was only what it took to start the engines and take off and go around the pattern, you know, 10 minutes of flying.

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Dr. MARTIN. Mr. Lewis, I am going to interject before Fitz answers. The AMK part of the test is all FAA's and NASA has—

Mr. LEWIS. All right. Then don't answer.

Dr. MARTIN. If you would be so kind, we would prefer not to answer.

Mr. LEWIS. I have great difficulty, the same as Mr. Carney, in saying anyone would survive this crash.

I have no further comments, Mr. Chairman.

[The prepared statement of Dr. Martin follows:]

HOLD FOR RELEASE UNTIL
PRESENTED BY WITNESS
APRIL 2, 1985

STATEMENT

OF

Dr. John Martin
Associate Administrator for
Aeronautics and Space Technology

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the

Subcommittee on Transportation, Aviation
and Materials
Committee on Science and Technology
House of Representatives

Mr. Chairman and Members of the Subcommittee,

I welcome the opportunity to appear before you today to discuss NASA's views on the preliminary results of the Controlled Impact Demonstration (CID) program and on our future research directions. I am accompanied by Mr. Samuel Venneri and Mr. Richard Tobiason to assist me in answering any questions you may have.

Mr. Engen has already described the overall NASA and FAA research objectives and assesement of some of the results to date. Today, I will summarize in more detail NASA's role and findings in this vital aviation safety research program and the direction NASA is going in future crashworthiness research. The CID program is the culmination of four years of intense work by NASA, FAA, and many participants in industry. This multifaceted safety experiment is the kind of work that is done very infrequently and was an ideal opportunity to integrate needed research in a timely fashion.

NASA has been involved in aircraft crashworthiness research for a number of years. In the years between 1972 and 1982, NASA Langley Research Center, in cooperation with the FAA and industry, conducted a very successful full-scale experimental program to measure the crash loads and structural response of general aviation (GA) aircraft (Figure 1). Test data from onboard instrumentation were acquired for impact dynamic

load characterization and correlation with results predicted by analysis. This activity led to the understanding of the dynamic response of GA aircraft structures subjected to impact loads and the development of validated analysis methods for crashworthiness research.

In 1980, NASA and the FAA initiated a study contract with three major transport aircraft manufacturers, Boeing Commercial Airplane Company, Lockheed-California Company, and McDonnell Douglas Corporation, to provide a review and evaluation of past transport accident data. The major objectives were to define a range of survivable crash scenarios that could form a basis for improving crashworthiness design technology and to identify test techniques and analytical methods needed to evaluate impact dynamic response of transport aircraft. The data base for this study began with a review of 993 world-wide jet transport accidents which occurred between the years 1958 and 1979 and from this number a combined total of 176 well documented survivable accidents were selected for detailed evaluation. The three contractors generally examined different accidents, but some accidents were reviewed by all three manufacturers as indicated in Figure 1. This study effort provided a definition of accident scenarios throughout the transport aircraft operational regime and provided a basis for establishment of the actual CID air-to-ground impact scenario.

Moreover, NASA Ames Dryden Flight Research Facility has conducted many flight tests of remotely piloted vehicle (RPV) aircraft in past years. Recently, much experience was gained during the RPV testing of the Highly Maneuverable Aircraft Technology (HiMAT) vehicle. For these reasons, NASA was invited to join the FAA in the planning and conduct of the CID program flight experiment.

For the CID program, NASA was responsible for two important functions: first, delivery of the aircraft to the impact area; and, second, collection of the aircraft structural dynamic impact data. A more detailed summary of these responsibilities is presented in Figure 2.

The Ames Dryden Flight Research Facility at Edwards Air Force Base, California, developed the remotely piloted vehicle flight control system and supporting simulator to deliver the unmanned aircraft to the designated impact site. Dryden developed an aircraft-ground telemetry system for transmitting aircraft control signals, and impact dynamic experimental data. Dryden also integrated the FAA Technical Center's AMK, fireworthiness and crash dynamic experiments as well as the NASA Langley Research Center's impact dynamics data acquisition system and associated instrumentation on the

aircraft. Other Dryden activities included airborne and ground photographic coverage, impact site preparation and coordination with the Air Force Flight Test Center for airspace, range safety and environmental consideration. Also, Dryden developed the overall flight readiness procedures and mission rules to establish safe flight operating conditions.

The NASA Langley Research Center was responsible for the selection and installation of the instrumentation for measuring the impact dynamic loads throughout the aircraft structure. Langley developed and qualified a Data Acquisition System (DAS), including hardware and software, for recording and transmitting aircraft impact dynamic loads. In addition, Langley developed a photographic system to provide onboard film coverage during the impact event. Overall, Langley was responsible for the acquisition of the structural response data, subsequent analysis of the data, and the development and validation of the aircraft structural model.

In preparation for the CID flight experiment, Langley conducted three transport fuselage section drop test experiments to obtain required understanding of the structural dynamic response of transport airframe structures. To evaluate and qualify the flight instrumentation, the DAS was used to acquire data during the drop tests of three instrumented B-707 fuselage sections. (The B-707 and B-720 fuselage structures are nearly identical.) The aircraft fuselage sections were dropped from a height of approximately six feet (Figure 3) to obtain a vertical impact velocity of 20 feet/second, representing the maximum sink speed in the CID scenario. During these tests, structural and passenger responses were measured and recorded using accelerometers and high-speed movie cameras. To evaluate the capability of current analysis methods to predict the dynamic response of the fuselage sections, finite element models of the fuselage, floor and seat structures were developed. The results of the analytical model were successfully correlated with the fuselage drop test results. The analysis solution accurately predicted the buckling of the fuselage bottom and the transmission of the loads throughout the fuselage shell structure. This information was also used in the development of the total CID aircraft structural model needed to establish the impact scenario. This analysis activity in conjunction with the three contractor studies defined the CID flight envelope parameters at impact: 145-155 knots forward velocity; 15-20 feet per second sink speed; and zero to two degrees nose-up pitch attitude.

The data acquisition system was installed onboard the aircraft to record and transmit data from 350

transducers located throughout the aircraft (Figure 4). Approximately 60 percent of the transducers, which included accelerometers, strain gages, and load cells, were located on critical airframe structural elements such as the fuselage frames, floors, wings and engines. The remaining transducers were located on the dummy passengers and seats to record their response during impact. The ten-camera photographic system was mounted to the ceiling throughout the cabin to record the motion of the dummies and the response of the interior structures. In addition, the DAS equipment and each camera was thermally insulated to insure protection of recorded data and film in the event of any onboard aircraft fire.

A critical technology challenge was the development of the large CID transport aircraft into an RPV. This conversion had never been done before. Dryden has developed unique expertise in this field over many years and for much smaller vehicles such as HiMAT. This recent experience was a key factor in developing the cooperative program. A complicated factor to overcome was the relative age of this generation of aircraft using cable-actuated flight controls and the near absence of documentation. Boeing was extremely helpful to Dryden in resolving this issue. Another complicating factor was the extremely small impact footprint dimensions of 30 ft laterally and 200 ft longitudinally. In retrospect, Dryden was required to deliver the unmanned aircraft to an impact area essentially within the allowable tolerances of a low visibility, instrument landing that requires sophisticated onboard autoland systems and ground-based electronic guidance.

The ground-based equipment included the ground cockpit, telemetry and communication systems (Figure 5). The ground cockpit was similar to the aircraft cockpit and contained all the instruments and flight controls for remote navigation and precise control of the aircraft. An aircraft-nose mounted video camera gave the pilot visual cues as he flew the aircraft to the impact site. Signals were transmitted to and from the aircraft using telemetry equipment and communication antennas. The aircraft flight was monitored and directed from the mission control room which was linked to the ground cockpit. Remote activation of all onboard recording equipment and cameras was accomplished from the ground cockpit.

A series of 14 manned flights between February and November 1984 were required to develop and flight qualify the RPV system, AMK degraders, data acquisition systems, telemetry and onboard cameras. Each of these areas presented challenges for timely resolution by both NASA and FAA and excellent cooperation was demonstrated by the project Technical Team and the Test Management Council.

I would like now to describe the actual demonstration flight on December 1, 1984, beginning with the aircraft approaching the impact site. It was a project mission rule that the airplane would be committed to impact when it descended through 150 feet above ground level. This was required to enable the activation of time-critical, limited-duration, onboard photographic and data recording systems. The apparent control problem the RPV pilot was having on final approach did not manifest itself until the airplane was below the 150-foot commit altitude.

The pilot had considered a go-around at 200 feet because the airplane had drifted right of the target centerline. He decided however, that there was enough time and altitude left to achieve an adequate alignment with the impact centerline. Three seconds later with the aircraft at the 150-foot commit altitude the pilot made a fairly sharp left aileron control input to move the airplane back to the target centerline. This control input initiated the lateral oscillation prior to impact. Knowing that he was committed to continue flight to impact, the pilot concentrated his efforts on damping the oscillation, achieving the best line-up possible, and assuring that the airplane impacted the ground in front of the wing openers.

The project personnel had discussed with the pilot the negative consequences of impacting beyond the wing openers. Those consequences could have been a total loss of the AMK experiment if fuel spillage was not achieved. It was mutually agreed that impacting short of the target was much preferable to impacting beyond the wing openers.

In retrospect, the pilot did an exceptional job of completing the first ever planned impact of a remotely controlled transport aircraft. With the airplane travelling at a speed of approximately 254 feet/second the left wing impacted the ground 285 feet or 1.1 seconds short of the planned impact area. The initial impact of the fuselage was within 0.6 seconds of the planned impact area. These results demonstrate that the desired impact goals were too constrained. Although the actual impact scenario was different in some respects, the value of the crashworthiness experiments was not compromised. All onboard instrumentation including cameras, performed as anticipated, providing researchers with an abundance of data which is presently being evaluated by NASA and FAA personnel.

The overall performance of the DAS and onboard photographic system was excellent. Ninety-seven percent of the transducers were active at impact and all ten

onboard cameras worked properly. The fire protection insulation prevented fire damage to all onboard recorded information even though the fire lasted for a significant period of time and was hot enough to melt aluminum structure. The onboard film provided unique insight into the propagation of fire and smoke in the aircraft interior.

The initial impact of the aircraft fuselage prior to striking the wing cutters was the event of interest for the crashworthiness experiment. The left wing impacted the ground first, followed by the fuselage section forward of the wing box striking the ground. The wing and forward fuselage impact greatly reduced the vertical load incurred in the remaining fuselage section. An example of typical structural response data for one accelerometer mounted in the forward fuselage sub-floor area is presented (Figure 6). This illustrates the structural response due to initial contact of the left outboard engine and then the dynamic response of the fuselage structure at impact. The fuselage impact pulse duration was approximately .15 seconds and is typical of transport aircraft dynamic response behavior.

The total fuselage impact loads were survivable using accepted criteria for human tolerance. The peak vertical acceleration loads along the floor were highest in the cockpit and forward cabin, approximately 15 g's. The remaining cabin floor received vertical acceleration peaks generally about 7 g's or less. The peak longitudinal acceleration levels showed similar distribution with the highest level being 14 g's in the forward cabin and levels generally less than 4 g's over the rest of the floor. Lateral impact load peaks on the floor were also generally low. They ranged from about 5 g's in the cockpit to 2 g's in the aft fuselage.

Some preliminary results have been compiled to determine the structural response interaction and load path definition at various locations along the fuselage at impact (Figure 7). In general, the loads were higher in the forward fuselage than in the aft section. This resulted from the nose-first impact of the aircraft which absorbed a large amount of energy. In addition, load transmission through the fuselage section to the subfloor and dummies was reduced by the crushing and energy absorption of the fuselage structure. For example, at fuselage location B, close to the initial impact location, in Figure 7, the peak vertical acceleration at the bottom of the fuselage was 32 g's. Significant fuselage structural deformation occurred such that this load was reduced to 7 g's before reaching the floor. The loads at the floor at this airframe location were approximately 6 g's for .15 seconds duration. At these low load levels and low frequency, no seat dynamic load amplification occurred during load

transmission to the dummy pelvis which also responded at approximately 6 g's.

Dynamic impact loads from the CID experiment were successfully recorded using the onboard DAS on magnetic tapes. These data, along with results from the aircraft dynamic analysis programs utilizing finite element models, will be collected into an impact data base (Figure 8). Access to the data base will provide industry and government agencies impact dynamics data for the development of load time histories and for the understanding of structural load path transmissions. These data will be correlated with analytical results to provide evaluation and validation of the analytical models which have been extended to a complete aircraft. Once these methods have been validated, additional analysis can be conducted to investigate the structural behavior due to changes in specific structural and flight parameters. In this manner information from other crash scenarios can then be evaluated.

With our current analytical capability, a transport-size aircraft can be modeled only using a series of nonlinear springs and beams. While this provides adequate loads prediction capability on a global level, in the future a loads prediction capability on a more detailed level is desired for actual structural component design and evaluation (Figure 9). Definition of detailed local loads and response characteristics in components such as fuselage rings, longerons, and panels can lead to improved crashworthy designs concepts. Eventually, modeling capability will be sophisticated enough that an entire airframe can be modeled with enough detail to determine local component failure mechanisms. In addition, advanced analytical methods incorporating more efficient solution methods will enable accurate prediction of these highly nonlinear structural problems on a routine basis.

I have given you some details about NASA's objectives, responsibilities, and preliminary results for the CID crashworthiness program. From NASA's viewpoint the experiment was very successful. We gathered an enormous amount of high quality structural response data, some of which we plan to release to industry at a joint NASA/FAA workshop scheduled for mid-April at Langley. Also, our future research work will continue from our current analytical capability, through detailed fuselage structural component modeling, to a capability which will encompass detailed modeling of a complete aircraft structure including local design details.

It has been my pleasure to discuss with you the NASA crashworthiness research regarding the CID program.

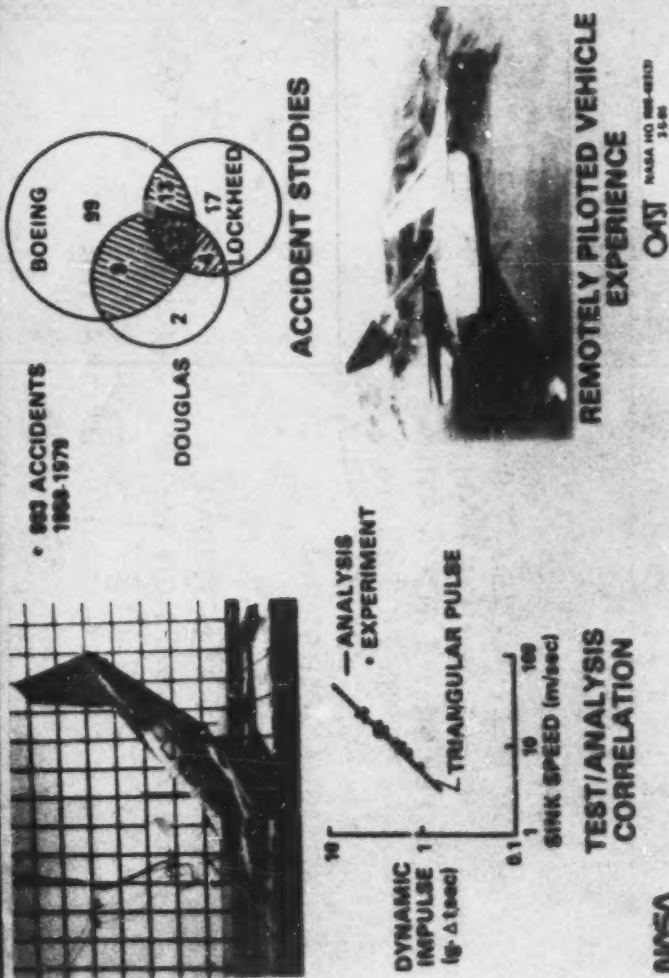


Figure 1

NASA RESPONSIBILITIES

AMES/DRYDEN

- REMOTELY PILOTED VEHICLE/FLIGHT CONTROL SYSTEM
- AIRCRAFT/GROUND INTERFACE - TELEMETRY
- EXPERIMENTS INTEGRATION
- IMPACT SITE PREPARATION
- EXTERIOR PHOTOGRAPHIC AND VIDEO COVERAGE
- FLIGHT OPERATIONS

LANGLEY

- STRUCTURAL INSTRUMENTATION
- DATA ACQUISITION SYSTEM - HARDWARE/SOFTWARE
- INTERIOR VIDEO COVERAGE
- IMPACT LOADS ACQUISITION/ANALYSIS
- AIRCRAFT ANALYTICAL MODELLING

NASA

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Figure 2

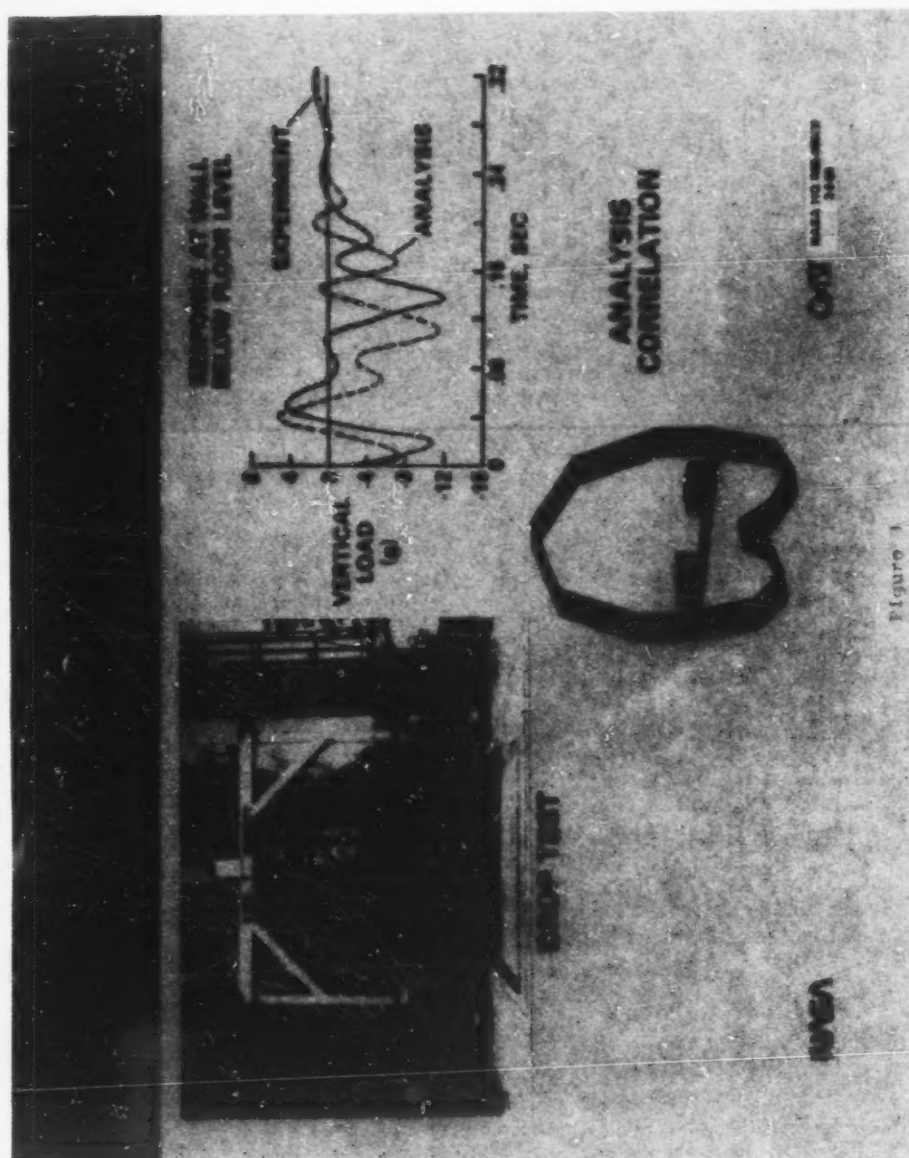


Figure 1

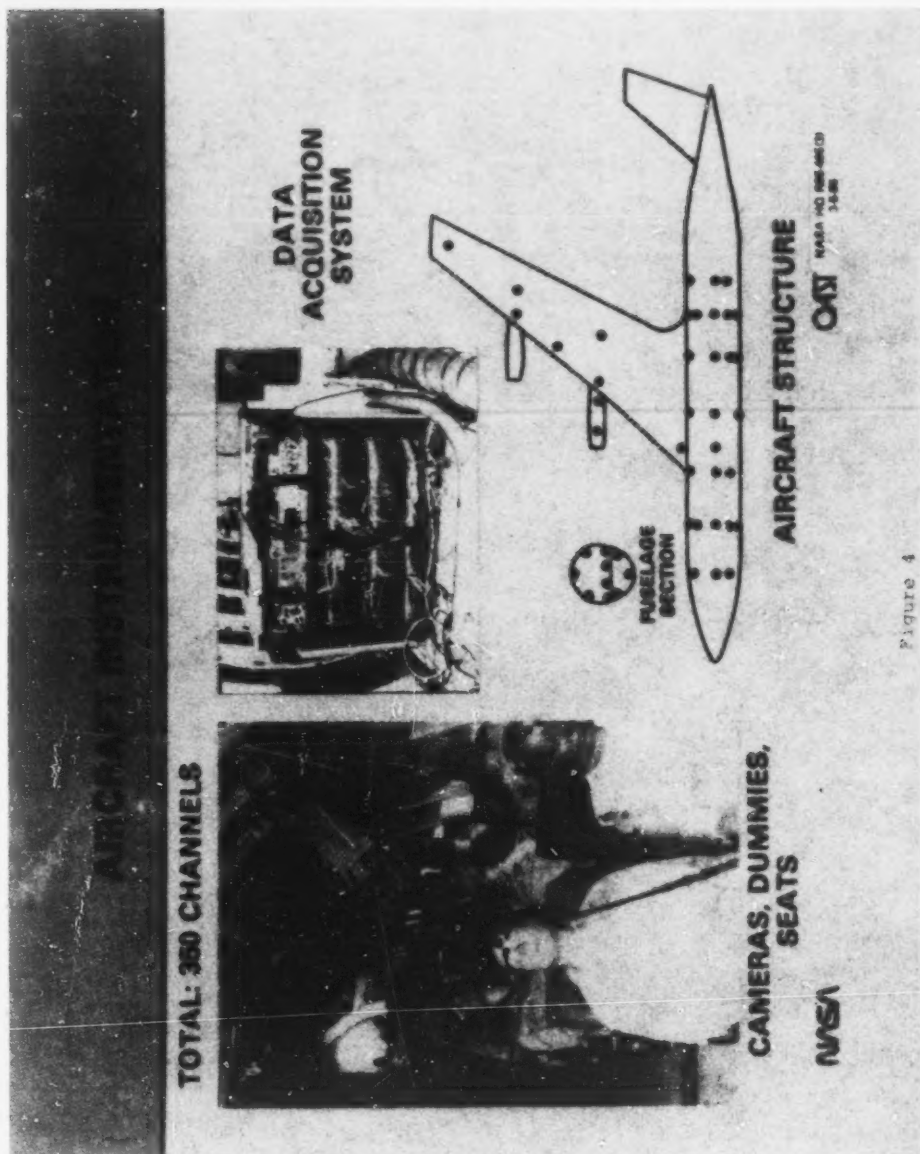


Figure 4



Figure 5

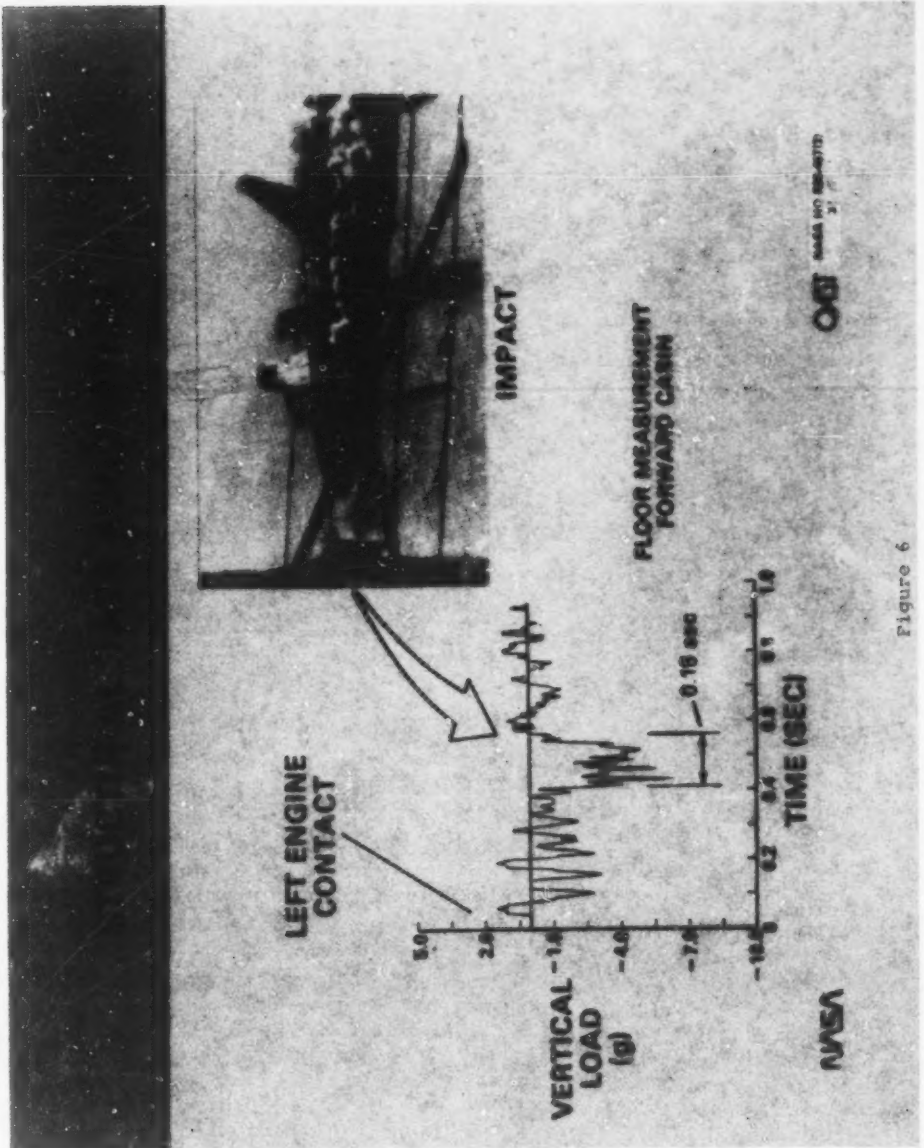


Figure 6

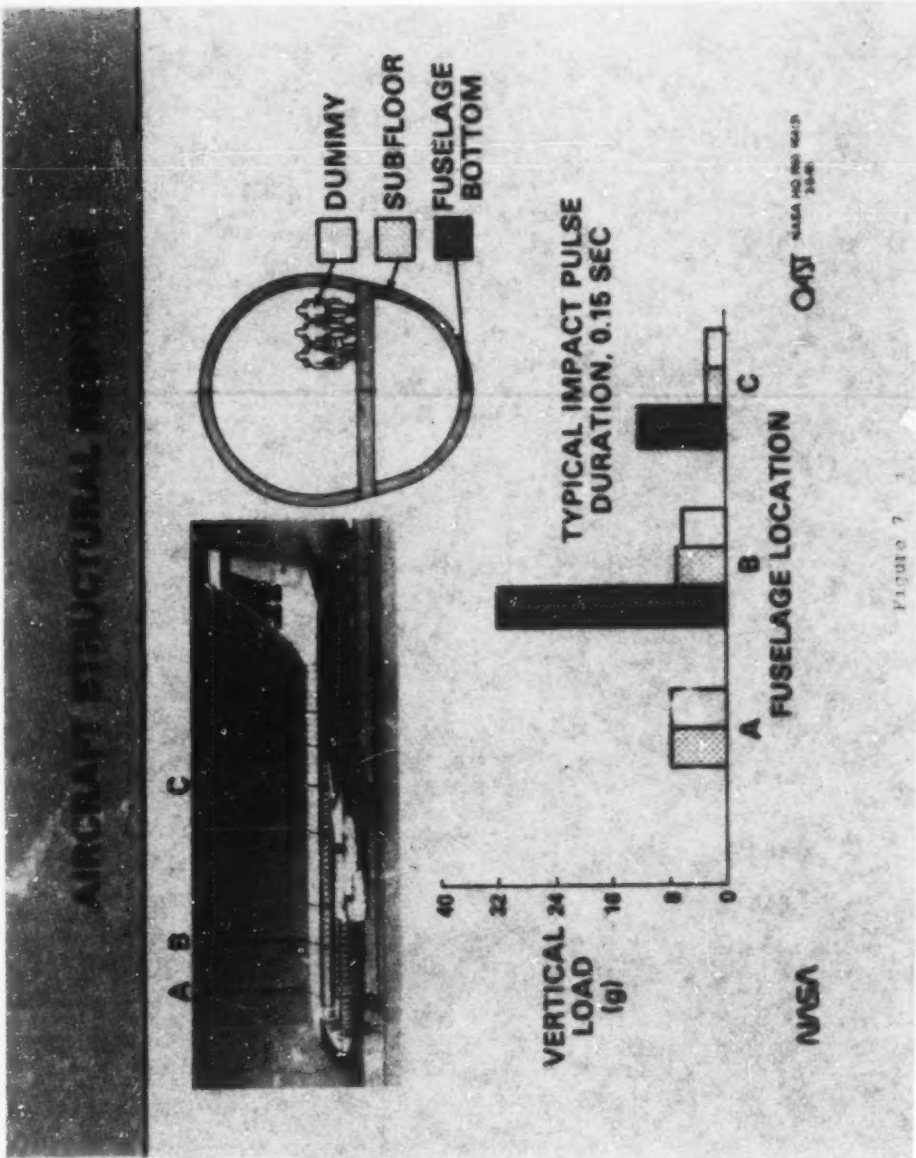
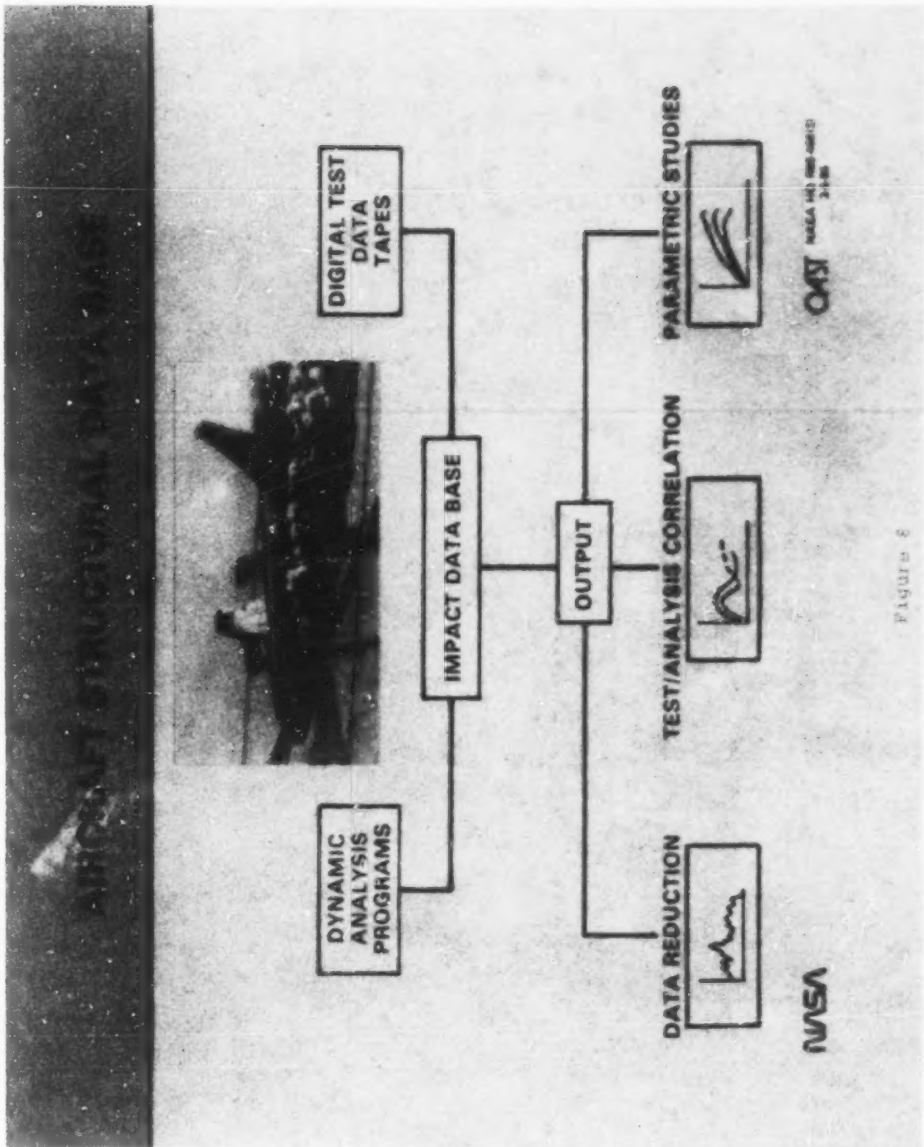
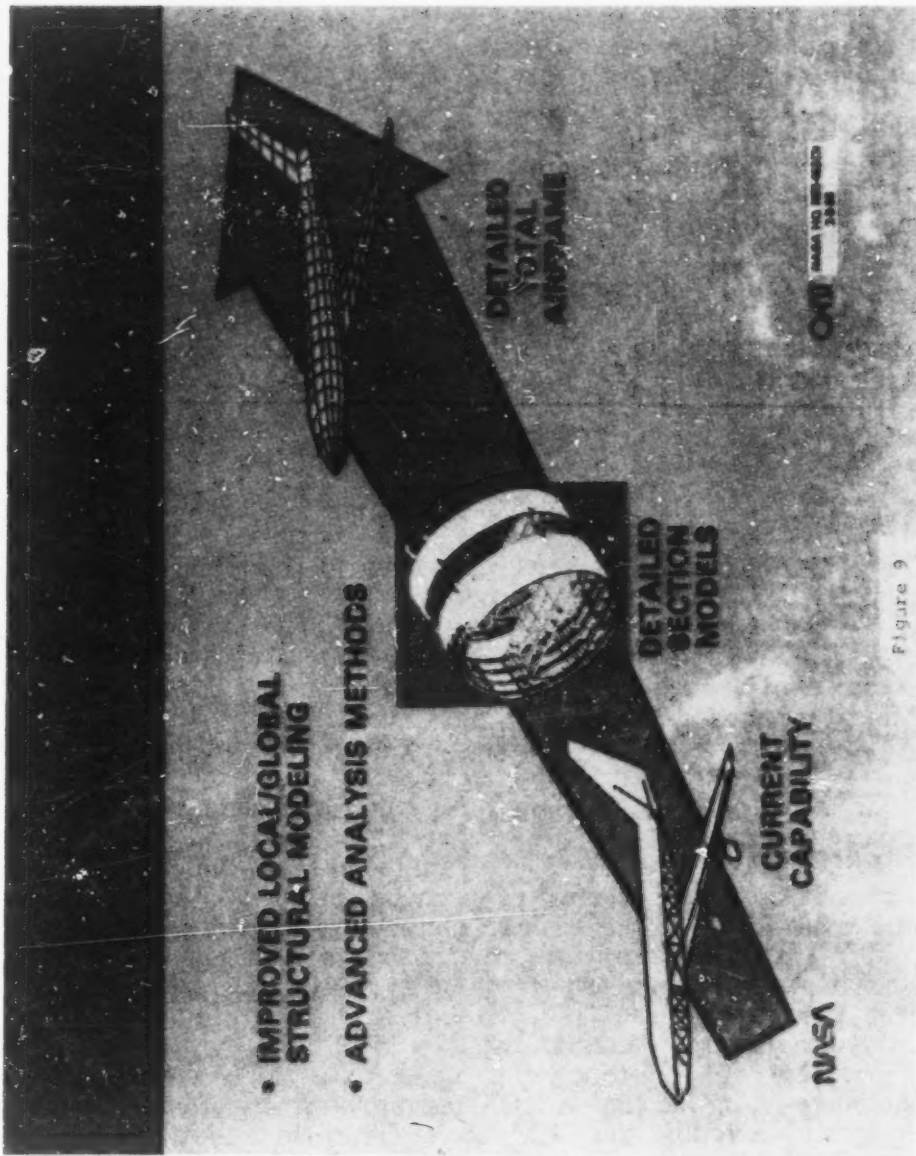


FIGURE 7





Mr. GLICKMAN. I want to thank you all for testifying and also for your fine work in participating in this. I also believe that it was extraordinary. The remote piloting of that plane was an extraordinary thing, and you did a good job there.

Dr. MARTIN. Thank you.

Mr. GLICKMAN. Thank you.

Our last witnesses, I think, are the manufacturer of the fuel. And I think they have a stake in telling us a little bit about the fuel that was used. ICI Americas, Inc., and the witness is James McAbee, the AMK Commercial Manager.

I understand you have both a statement for the record as well as an oral statement. Your statement for the record will appear as part of the record. Why don't you go ahead and proceed with your oral statement. You may just push that button when you want the mike turned on.

**STATEMENT OF JAMES McABEE, AMK COMMERCIAL MANAGER,
ICI AMERICAS, INC., ACCOMPANIED BY CHARLES RIVERS,
TECHNICAL PROGRAM MANAGER**

Mr. McABEE. Good afternoon, Mr. Chairman and members of the committee. I welcome this opportunity to appear before the committee on behalf of ICI Americas. Our president, Mr. Harry Corless, is unable to attend and asked me, James McAbee, the AMK Commercial Manager, to extend his apologies and represent ICI Americas here today.

Mr. GLICKMAN. Could you move the microphone a little closer to you so that we can hear a little better?

Mr. McABEE. Also with me is Mr. Charles Rivers, our technical program manager.

ICI Americas is involved in a number of aviation safety areas such as Halon 1211, clean fire extinguisher, that is used in flight line and onboard power extinguishers, as previously mentioned by Admiral Engen, deicers, aircraft structural components of high-strength polymers, and fire-blocking layers for aircraft seats. However, today I will focus on our role in ICI's Avgard antimisting additive used in antimisting kerosene at the CID.

First, I would like to say that the FAA is to be commended for the outstanding job that it has done on the AMK program leading up to and including the CID, and for improving aviation safety. It is always difficult to assess the cost benefit of aviation safety improvements. This fact should not and has not deterred the FAA's efforts to improve safety and post-crash fire survivability, especially now that we have the newer widebodied jets which can carry 300 to 400 passengers.

ICI is one of the world's major chemical companies, with large sophisticated research capabilities. We have spent 17 years, and millions, in supporting our belief that AMK is a viable approach to reducing post-crash fires. The novel technology in FM-9 polymer, the major ingredient in our Avgard antimisting additive, was designed not only to impart antimisting, but to meet aircraft operational demands of dissolution in jet A, pumpability across wide fuel temperature ranges, degradability, and low-cost effective con-

centrations. To date, we believe all of these have been proven in the test program leading up to the CID.

Aviation has an excellent safety record, and it is one of the safest modes of transportation. But the CID reinforces the need to improve cabin safety and post-crash fire protection. To this end, ICI still believes antimisting kerosene is the best approach to saving lives in a post-crash fire, utilizing the latest available technology. AMK warrants this committee's, the FAA's, and the aviation industry's continued support and investigation, especially taking into consideration the very positive pre-CID AMK test results, the wealth of data pointing to AMK's efficacy, and the CID itself.

The CID wasn't to prove AMK, but demonstrate its capabilities for improving post-crash survivability. We believe that until a thorough investigation by the FAA is completed, it is preemptive to pass judgment on AMK's total effects.

The CID did demonstrate the already known fact that AMK will not equally protect against all serious fires and all aircraft accidents, but primarily those where misted fuel is exposed to ignition sources, which we understand represents the majority of all fire-related survivable crashes.

It should be recalled that CID was planned to simulate, using a representative transport plane, an impact-survivable, wheels-up landing accident short of the runway. We accept accidents are not planned. However, we think the actual CID did not provide AMK an opportunity to demonstrate its benefits. The effects of the numerous sharp obstacles, wheels up, full-fuel load, severed engine—which was the ignition source—remaining attached to the aircraft, and side-angle slide were so cumulative, they probably represented the worst-case scenario.

Since ICI Americas was not part of the followup investigation team, our analysis is based on reviewing only 5 to 6 hours of film records and discussions with the FAA. Originally, ICI was disappointed with the perceived CID results, but not discouraged, especially after considering the positive benefits which are now emerging.

To digress for a minute, as to Congressman Carney's statement, we did not have those facts at the time he saw us right after the CID.

No. 1, the fuel onboard the CID Boeing 720 met the AMK standards established by the FAA and ICI. No. 2, the aircraft flew satisfactorily with all four engines on AMK, confirming the flight performance of the Convair 880. No. 3, the rate of flame propagation, while severe, was far less than had been previously measured on large-scale tests with jet A. Had the CID been a real accident, it would have been deemed survivable with respect to both impact and fire. And there is evidence that the plane was damaged by an interior cabin fire rather than the unmanageable fireball. This would have allowed more time for passengers to escape.

It is, therefore, our conclusion that AMK did contribute to reducing the severity of the post-crash fire by lessening the rate of flame propagation and fireball size, intensity, temperature, and duration. We believe AMK had little opportunity to demonstrate the full benefit of its designed antimisting function.

above a hot ignition source, the engine. Therefore, liquid fuel, not fuel which had been put into a form where it was misted so it couldn't burn, but literally liquid fuel fell down onto this engine, vaporized, so that the actual performance for which AMK was designed never had an opportunity to be demonstrated.

Now, even with this, I think there were benefits such that it was a much cooler fire. It only went to 200 degrees.

Mr. GLICKMAN. Well, I think that is a very important distinction that needs to be made here. There are several. One is, you can't predict what's going to happen in an accident.

Mr. McABEE. Yes, sir.

Mr. GLICKMAN. And therefore, if you had put all your eggs in the basket—which I think a lot of people did; when they saw the fireball, they were very disappointed—but the benefits of your fuel occur in the misting and antimisting characteristics, not just sitting on a big glob of fuel that is burning, because it will continue to burn even if it's the fuel with the polymer that you have in it.

Mr. McABEE. Yes, sir. And it may be in fact that we need some cumulative approaches, not only AMK but look at something relating to the engines or things of that nature, because, as I said, the design function—and going back to an earlier statement, we were pleasantly surprised with the results that it kept the skin temperature down to about 200 degrees.

In answer to Mr. Lewis' question, I have some pictures here which I brought along. You were asking about a jet A fire. There is a picture of the Lakehurst Jet A plane with the same amount of fuel that spilled out of the plane at the test at the CID. You cannot even see that plane.

Mr. GLICKMAN. Let em see the comparable AMK picture.

Mr. McABEE. Identical test, AMK picture. That's the two different—same amount of fuel, 2,900 gallons of fuel. These tests were conducted at Lakehurst.

Mr. GLICKMAN. Of course, again that is where the AMK is doing what it's supposed to do.

Mr. McABEE. Yes, that's right. That's what was done with this testing, yes, sir. But the thing to remember is that we were pleasantly surprised when it only got to 200 degrees, because that skin of the plane melts—and I am not an expert in aviation, but I understand from the FAA—at around 400 degrees. A jet A fire reaches about 700 degrees. So it does not take long for you to burn through the hull. With AMK, it would never get up to the temperature to melt through the hull, so that we were stuck then with the area where the plane was sliced open, pulling fuel inboard, and we did not have the liners and the fuel went into the cabin.

Mr. GLICKMAN. Now, what specific recommendations would you have to the FAA in terms of antimisting fuel?

Mr. McABEE. Earlier, after listening to Mr. Carney, I was glad to hear him say this was an experiment. And I sort of feel like saying don't throw the baby out with the bathwater. I think there is a lot that has been gained from the CID.

I think the FAA should continue on a program investigating additives for antimisting kerosene, potentially looking at augmenting the additive with other things that could be implemented. Not being an aviation expert, I can't comment further than saying

maybe some shutoff valves or something like that to prevent what happened at the engine.

But I think that we are on the right track, and as you said earlier, if we stop now after we have made giant strides—we are in trouble.

Mr. GLICKMAN. OK. Thank you.

Do you have any questions?

Mr. LEWIS. Yes, just a couple of questions.

Mr. McAbbee, I guess I am concerned the way you are concerned that you didn't have ideal simulated crash conditions. I have never seen an airplane that crashed crash-perfect, and I don't think that's going to happen. Now, your photos are very interesting to me, with the Jet A and with the AMK. But in addition, I would be concerned that there is always going to be an ignition source, whether it be an engine or whatever, when an airplane crashes.

So what is AMK going to do to prevent this sort of thing and avoid an ignition?

Mr. MCABEE. Well, AMK was designed, as I mentioned earlier for the antimisting scenarios which we had been led to believe and understood was for the majority of aviation accidents where fire fatalities have occurred. The FAA, it is my understanding—I suggest you direct the question to them—was studying whether or not or how probable the CID was with respect to all past accidents. It was highly—and I emphasize highly—improbable that the ignition source stays attached.

Above and beyond that, I say go to the FAA and they will tell you. But I believe that the AMK was designed—well, I mean I know it was designed for protecting what was predominantly the cause of fires, and that's where the ignition sources do not usually stay attached to that aircraft.

Mr. RIVERS. Mr. Lewis, if I may add, the difference between ignition of a misted fuel such as Jet A and an antimisted fuel is not whether an ignition source is present, it's the intensity of the ignition source required to cause ignition to take place. And here is where there is a dramatic difference between Jet A and AMK.

[The material referred to follows:]

Regular Jet A fuel will ignite easily if spilled during a crash—only the slightest, smallest ignition source such as a spark, or static electricity is necessary to start the well known fireball and create an inferno which cannot easily be survived by passengers.

AMK, on the contrary, will not easily ignite, and will not propagate into a large fireball with a small ignition source. AMK, to develop into a large fireball and subsequent inferno, requires the most severe crash scenario such as seen at the CID, where a large intense heat source continued with the spilling fuel.

So while it is very likely to have a fire with Jet A, it is very unlikely to have a fire with AMK. The FAA can speak to percentages of fire risks.

Mr. LEWIS. I guess maybe I just don't know enough about AMK and I better study it. But I would say 95 percent of the aircraft crashes that we have of this type, you're going to have a fire. And it doesn't make much difference to me what type of spark it is, and what you're telling me is it's the intensity of the spark that's going to cause the fuel to ignite. Is that true?

Mr. MCABEE. No, sir. To get back to the intensity, it's not how hot. For example, I believe if you look at Mexico City, where that fire started at the aircraft, after it hit a telephone pole and severed

a wire. The tank had split open and fuel was spilling out. If that fuel had not been misting but had been in the antimisting form, it probably never would have set off in a fireball.

Or if you open a wing in the front and the fuel isn't misting, and it gets to the rear engine, say, on a DC-9, it probably would not light off, because you're not in a misted form. But when you have that vapor coming right down onto a hotplate or a stove, it was never designed to protect for that. And I think the misconception is that it was not going to burn. As I heard the news media one night, "The FAA is still working on incombustible fuel." That wasn't what it was.

Mr. LEWIS. No further questions, Mr. Chairman.

Thank you.

[The prepared statement of Mr. McAbee follows:]

STATEMENT OF JAMES L. MCABEE

AMK COMMERCIAL MANAGER

ICI AMERICAS

ICI Americas appreciates the opportunity to submit our position on antimisting kerosene (AMK) and the December 1984 Controlled Impact Demonstration (CID) at Edwards Air Force Base, Lancaster, CA.

ICI Americas has long been involved in programs and products related to aviation safety and fire hazards. Our Halon 1211 fire extinguishant is used in portable extinguishers worldwide in commercial and military aircraft and ground support facilities. We supply deicers to the military. We have major research and development programs in conjunction with government and industry addressing seat fire blocking materials and panel/structural high strength polymers. However, this position paper will focus only on our role in ICI Americas' AVGARD® antimisting kerosene additive utilized in the FAA's AMK program and the CID.

ICI, a major worldwide chemical company with sales of \$13 billion, has been keenly aware of the concern over aviation post-crash fuel fires since the mid 1960's. Soon after the Royal Aircraft Establishment (RAE) first approached ICI, it became evident that ICI should commit support to combat aviation fuel fire deaths. This was reinforced during the 70's with the introduction of large wide body jets carrying 300-400 passengers. This concern translated into an intense in-house ICI Research, Development, and Engineering effort well in excess of \$10 million.

Naturally, any safety improvement in aviation, like those in the chemical industry, have an associated cost. It is always difficult to assess the cost/benefit of aviation safety improvement. However, this should not deter or lessen safety research efforts or potential implementation of post-crash fire protection.

Aviation has an excellent safety record and it is one of the safest modes of transportation. For considering possible further improvements to aid post-crash survival, the FAA appointed a Special Aviation Fire and Explosion Reduction (SAFER) advisory committee which included industry participation. In 1980 they concluded that "in evaluating both existing and proposed fire hazard reduction systems, the use of antimisting fuels has the greatest potential for improved safety by essentially eliminating the development of fuel fires in a post-crash environment...the research on such fuels should be expedited".

The FAA is to be commended for the outstanding work it has done in proving the AMK concept culminating in the CID program. We believe until a thorough investigation has been completed by the FAA, it is preemptive to pass judgment on the CID.

AVGARD® and FM-9® are trademarks of ICI Americas Inc.

However, ICI Americas still believes antimisting kerosene is the best available approach to post-crash fire protection utilizing the latest available technology. AMK warrants this committee's, the FAA's, and aviation industry's continued support and investigation. Especially when taking into account the very positive pre-CID AMK test results and wealth of data pointing to AMK's efficacy.

To better understand the role which ICI's AVGARD® antimisting additive is expected and was developed to play in suppressing post-crash fires, it is necessary to understand some of the mechanism involved in ignition and combustion of liquid fuels. The following terms are fundamental to such an understanding:

Vapor - A substance in the gaseous state as distinguished from the liquid state. All liquids co-exist with their own vapor; as temperature is increased, greater relative amounts of vapor are present.

Mist - A mass of finely divided liquid droplets, which may appear as a cloud.

Ignitable Mixture - A fuel/air (oxygen) mixture which can be ignited and which will support combustion when the ignition source is removed.

Flash Point - A property of combustible liquid, defined as the temperature at which sufficient vapor is present to form an ignitable mixture with the air above the liquid.

Many liquid fuels have very low flash points (e.g. gasoline, -45°F) and at normal temperatures, their vapors form ignitable mixtures with air. The ignition mechanism of these fuels, therefore, is one of vapor ignition.

However, other fuels with higher flash points (e.g. kerosene, over 100°F) are not as susceptible to vapor ignition at normal temperatures and must be heated to produce vapor before ignition can take place.

If these high flash point fuels are present in an aggregate state, such as a pool, ignition is relatively difficult to achieve. However, if these fuels are broken up into very small droplets as a mist, then an ignition source will rapidly warm individual tiny droplets to temperatures above their flash point and ignition will take place. Each burning droplet warms and ignites the small, close neighboring droplets and a rapidly developing fire results.

This is the phenomenon that frequently occurs in a jet aircraft crash when wing tanks are ruptured and kerosene fuel is released. The forward momentum of released fuel hitting the air stream shears the fuel into a mist and ignition is easily achieved. A mist "fireball" results and travels rapidly

(propagate) to the fuel release point. Although the fireball lasts only a few seconds, it has sufficient heat intensity to ignite spilled (pooling) fuel.

AVGARD® antimisting additive was specifically designed to reduce the tendency to form a fuel mist cloud. When the additive is dissolved in the jet fuel, it gives the fuel the property of thickening when subjected to shearing forces, thereby resisting break-up into tiny mist particles. Typically, AMK breaks up into relatively large droplets which are much more difficult to ignite since they act as small heat "sinks" and, even if ignited, are less densely packed than in a mist so that one burning droplet is less likely to ignite another.

AVGARD® does not in any way affect fuel vaporization, nor does it change the flash point of the fuel. Furthermore, AVGARD® is not an extinguishing agent; it does not make the fuel any less combustible than the base material.

Therefore, in situations where AMK fuel is warmer than or heated to a temperature above its flash point, AMK will still function to prevent mist, but vapor ignition can take place locally. However, the rate of flame propagation in the cooler areas away from the heat source would still be slow in relation to propagation through a normal Jet A mist.

Capitalizing on this antimisting phenomena, ICI spent 17 years developing and modifying additives to impart antimisting behavior to jet fuel and meet other operational demands. From the beginning, it was obvious that the modified fuel needed to do opposite things: burn in the engine but not when spilled from the wing. Besides developing a fuel additive which performed opposite functions, we had to consider four other key elements.

The additive has to dissolve in jet fuel in 15-30 minutes so not to prolong refueling times. The modified fuel has to be pumpable across a wide temperature range so it would function during typical flight conditions. The fuel has to be "degradable", which means the additive's properties can be destroyed before it reached the engine so the fuel would mist. Finally, the additive had to be able to work at low concentrations, not only for cost reasons but also for the benefit of handling and logistics of the additive at airports. The result of this search is the AVGARD® slurry additive containing FM-9® polymer.

In 1978, the FAA assumed responsibility for examining feasibility and operational performance of AMK.

In carrying out this role, the FAA set four objectives:

- o Determine the feasibility of AMK
- o Demonstrate the effectiveness of AMK
- o Assess the cost of AMK
- o Develop recommendations for use in civil aviation

In order to achieve these objectives, the AMK technical team had to consider several factors. First, the modified fuel's flammability performance, rheology, production, and specifications. Secondly, AMK's compatibility with aircraft fuel systems, engines, and airport refueling systems. And finally, the cost/benefit of utilizing AMK.

ICI will focus on the first two objectives -- feasibility and operations.

In assessing feasibility, the FAA was supported by ICI Americas and the research facilities of Southwest Research Institute and Jet Propulsion Laboratories. At their Technical Center in Atlantic City, NJ, the FAA performed over 300 wing dumps at various speeds, dump rates, and different ignition sources. Tests were then scaled up to simulate real aircraft performance by catapulting six different aircraft at operational landing speeds with severe fuel releases and exposure to numerous ignition sources. These tests confirmed earlier, positive results. The control test with standard unmodified Jet A resulted in an explosive fire which destroyed the aircraft. All other tests used Jet A modified with ICI's AVGARD® and demonstrated fire suppression with the aircraft fuselage essentially undamaged by fire.

Many tests and developments have been conducted to validate AMK's operational properties. A prototype in-line additive/fuel blender has been developed and satisfactorily demonstrated before and at the CID. Prototype degraders have been developed and utilized on a Convair 880 and the CID Boeing 720 producing engine performance on AMK similar to Jet A. Adequate quality control techniques to evaluate AMK's efficacy are in place, although commercial operational quality control techniques still need development. Aircraft fuel management and fuel environmental effect tests were also conducted. Short term, engine tests have been carried out at the FAA's Technical Center. And, most importantly, a Convair 880 has conducted 44 hours of ground and flying tests with one engine on AMK.

Based on these tests, it was concluded that AMK provides protection up to 150 knots, typical landing speeds. Flame propagation rates and intensity are much lower when fire does occur. Dissolution via the in-line blender is achieved in 15-30 minutes. All the basic feasibility and operational testing have confirmed AMK is technically sound. Necessary equipment critical to AMK's performance and blending has been developed. It can be positively stated AMK has met all the original demands placed on the concept and its performance.

Thus, we are left with the CID and it's implications on AMK. The CID was to demonstrate AMK -- not prove it. Did the designed function of AMK, antimisting, have an opportunity to manifest itself and did AMK contribute beneficially to the CID's outcome?

Since ICI Americas was not part of the follow up investigation team, our analysis is based on reviewing 5-6 hours of film records and discussions with the FAA. It bears restating that FAA's Full Scale Transport Controlled Impact Demonstration program AMK objective was to "verify that an antimisting fuel can preclude ignition of the airborne fuel mist or suppress the ignited fireball growth rate and demonstrate an operational/propulsion system capability".

The CID did show the operational fuel/propulsion system capabilities of AMK from blending through feeding the engines with all four engines performing satisfactorily.

The fuel on the CID Boeing 720 met the AMK rigid standards established by the FAA and ICI. This was confirmed by the FAA, Jet Propulsion Labs, and ICI Americas' analyses. Following is ICI's average values for seventeen different CID fuel samples:

<u>Test</u>	<u>Actual</u>	<u>Specification</u>
Flow cup (mls/30 sec.)	1.7	Less than 2.5
Filter ratio	77.0	35 - 100
Solids	0.299	0.30 $\pm$.01

Addressing the issue of whether an antimisting fuel can preclude ignition of the airborne fuel mist or suppress ignited fireball growth rate is more difficult. The conditions of the CID were very severe, if not unique. Many probable accident criteria were included in the designed conditions. The fact of wheels up, numerous sharp runway obstacles, full fuel load, engines hitting obstacles sideways, ignition source (engine) staying attached to the wing, side-angle slide trapping fire against the fuselage as a flame holder and fuel entering the cargo bin through the numerous fuselage cuts probably produced the worst case scenario. In retrospect, this may have contributed to an atypical accident scenario. This we understand will be determined by the FAA.

Based on the FAA's preliminary analysis of film footage, evidence points to the fire starting at the severed #3 engine which came to a complete stop in less than a revolution. This in itself is a rare event and would produce an explosive heat release, i.e. ignition source. A tear in a wingtank near this engine resulted in liquid fuel (not misted) spilling directly onto this intense ignition source, raised the fuel's temperature to it's flash point, and a fire ensued.

Based on the FAA's assessment, it appears AVGARD® modified fuel reduced the rate of flame propagation and the magnitude of the "fireball". Although the antimisting properties were present, the antimisting phenomena did not play a significant role in the ignition of the fire since fuel vaporized and immediately ignited.

Even with the initial, short duration fireball and the more damaging internal secondary pool fire which eventually burned through the cargo bin containing trapped fuel, many benefits are surfacing attributable to AMK. According to the FAA, the following can be concluded:

- o The aircraft flew satisfactorily with all four engines on AMK.
- o The accident was very likely fire survivable which is unusual for a crash of this severity.
- o The rate of "fireball" flame propagation was considerably less than previously observed or measured on large scale Jet A tests.
- o The plane appears to have been destroyed by the secondary internal pool fire rather than an unmanageable fireball.
- o The #3 engine was the only place fire started during slide out. Fuel may have been released from other points but did not ignite.

Therefore, it is ICI's view, based on this limited CID review, that AMK did satisfactorily demonstrate an operational fuel/propulsion system capability and contributed to lessening the severity of the post-crash fire by reducing the fireball's propagation rate, size, intensity, temperature, and duration, thereby adding valuable time for passengers to escape. These benefits when combined with pre-CID data supports a continued evaluation of AMK which still offers the best opportunity for post-crash fire reduction and survivability.

ICI Americas recommends a continuation by the FAA of a funded AMK technical program leading to an NRPM/mandate. Periodic reviews will be necessary to determine if new data dictates program redirection. We also recommend that the aviation industry be included in program planning as subcontractors in their areas of expertise and for conducting engine evaluations.

A continuing AMK technical program of the FAA should include:

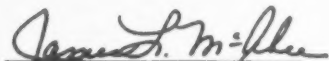
- o Additional AMK and Jet A wing dump trials to evaluate more intense ignition sources and engine ingestion effects at various positions in relation to the fuel release point.
- o Continued Convair 880 flights to further evaluate operational performance.
- o Improvement of the in-line blender and degrader to a ready commercial state.
- o Long term engine endurance trials.

- o Limited operational fleet trials.

Regarding cost/benefit, ICI firmly believes the flying public is willing to pay \$2.00-4.00 additional cost per ticket for an average 1,500 mile flight to have the AMK benefits available in the fuel.

As a supplier of antimisting additives, we recognize the U.S. Congress and the FAA are the motivating forces behind AMK. Therefore, as in the past, we will respond in an appropriate manner to the conclusions by this committee and the FAA, and ICI will give continued and appropriate support to the FAA.

I hope this has clarified ICI Americas' position and support for AMK. We appreciate you providing ICI Americas the opportunity to submit this testimony.



JAMES L. McABEE
AMK COMMERCIAL MANAGER

Mr. GLICKMAN. We have two bells going off at the same time.

Thank you for your testimony. We appreciate it very much. This will conclude the hearing today.

I would just make a couple of points that I think that need to be done from our perspective. One is, I think it's clear the FAA needs to continue research into the issue of antimisting fuels. They are not ready to promulgate a rule, but neither are they ready to drop the issue. And I would hope that that will be continued and this subcommittee will do its best to fund that research.

The second thing is, the most significant thing that came out of this hearing today is that the FAA's desire and agreement to go ahead with the notice of proposed rulemaking on seats, strengthening seat standards, is something that I think should have been done 10 years ago, that the validation of seat strength technology is about a decade behind, that those seats could have gone into the existing new generation of airplanes that are being manufactured today at I don't think very much of an additional cost, if any at all. We waited an awful long time to do that. But at least the decision has been made to move ahead with that.

It's kind of the perennial problem that we have between the regulatory side and the congressional side. I do have confidence in this Administrator, however, that he is going to do whatever he can to push ahead within the confines of the pressure that he has.

But I think the CID test was a valuable test, and I think that notwithstanding my colleague from New York's concern about the size of the fireball, I wouldn't have wanted to be in it either. But the fact of the matter is I think it did yield some incredibly valuable results, and I hope that private industry, the airline industry, the manufacturers and the Government can move ahead to do what we are mandated to do, and that is to make flying safer in this country. Given that, I think that the test is a very valuable one.

So if there are no other comments, the hearing is adjourned for today.

[Whereupon, at 2:55 p.m., the subcommittee was adjourned.]

APPENDIX

Report of

James Matthiesen
Aviation Consultant

April 2, 1985

Hearing on Controlled Impact Demonstration
Subcommittee on Transportation, Aviation and Materials
Committee on Science and Technology
U. S. House of Representatives

As an independent consultant on transport aviation, James M. Matthiesen was hired by NASA Dryden for the Controlled Impact Demonstration (CID) as a temporary employee with the job title of expert.

It is believed that the test was a technical success, but there are some reservations on the readiness of the anti-misting kerosene to be used in commercial jets.

The test itself was a severe one for both the airplane systems and the fuel. The world's largest "barbecue pit" was constructed as a slide out site. The rock base acted as a "heat sink" to boil the fuel for the sustained fire that occurred. However, there were at least three firemen inside the fuselage until the fire was out!

The crash scenario was not a typical crash! A study of the 176 crashes reviewed by Boeing, Lockheed, and McDonnell Douglas will not show a fuselage sliding through two sets of impact obstacles that would shear both of the wings off, allowing the fuselage to slide free of the "ball of fire"!

As the actual CID occurred, it was a type of crash. (i.e. blown tires on one side causing the airplane to veer and collide with a construction vehicle parked too close to the runway -- Rome early 60's).

It is evident that "tenerife" would have merely been a cooler fire by a few hundred degrees -- scant consolation to the victims and their families. The protection margin (percent of additive to the jet "A") was designed to protect 160 knots, which protects only the airframe velocity. The exhaust gas velocity, directly behind the engines, is at several hundred knots, at high powers of an attempted go-around.

An increase in the percentage of the additive would, of course, improve the flame resistance of AMK fuel, but it would further complicate the storage and delivery of the fuel to the airplane tanks and engines.

The unknowns in the blending, handling, storage and use of the AMK fuel in a normal operation are of the greatest concern. Premature mandating of the use of AMK could cure the fever by killing the patient!

During the CID project, one of the rules put down by the FAA was that there could be "zero" mixing or interfacing of AMK and set "A" fuels.

A major modification of the fuel system had to be made in an attempt to solve this problem. It was impossible to prevent an interfacing of jet "A" and AMK in the plumbing, however, and a strict adherence to new operating procedures were required to minimize the problems.

Introducing AMK to a tank which had contained jet "A" called for purging of that tank with an AMK flush of that tank -- even though it was demonstrated that only a pint or two of fuel remained after draining the tank.

Because of the interfacing of the two fuels in the plumbing, it was necessary to add a glycol additive to the jet "A" fuel to prevent a dropout of the polymers in the AMK at the interface. However, even with the additive, our instruments showed a pressure spike when AMK was introduced to the engine.

Blending of the AMK fuel at the desert sites was highly successful, but reports from Miami and Atlantic City with the convair 880 tests showed a high water content and filter clogging along with gelation on some parts of the fuel system. Batting .500 is fine for baseball.

None of the fueling was done through the normal underwing fuel system. All of the AMK fueling was done over the wing. It is safe to say that this was a first for this aircraft! The final product must be delivered normally, through the underwing system, without fear of degradation of the fuel.

The final test flight was made with a batch of fuel made for this flight only. All of the jet "A" and all of the AMK already aboard had to be drained and the tanks flushed prior to the final flight.

The jet "A" used for the blending was from a single manufacturer and was checked in a rigid specification. It took six hours to blend and load the fuel at the airplane. With that time frame, we will double the fleet of jets without hiring another pilot. The fuel must be capable of normal storage and normal delivery without being degraded in the process.

Several questions must be answered:

1. What is the shelf life or operational life of AMK?

Some of the original batch of fuel, however small, put aboard the aircraft will still be aboard when the aircraft is melted down to make another machine.

2. How much, if any, jet A or another batch of AMK can mix with the residual fuel aboard an aircraft?
3. Is the AMK quality uniformly consistent when the basic jet "A" source is changed? (i.e. shell instead of mobil, etc.)
4. Can the blending be quality controlled by the average fueler -- or must we build a computer controlled blender at each fuel site?
5. Is it worth the cost? Could we better spend the money for safer airports; guidance systems; ATC control; and make the airplanes themselves safer?

